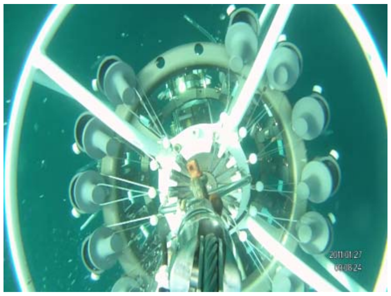
Chapter 3

COASTAL OCEANOGRAPHY AND WATER QUALITY



Chapter 3
COASTAL OCEANOGRAPHY AND WATER QUALITY

INTRODUCTION

To evaluate potential impacts to the marine environment and public health, the Orange County Sanitation District (District) measures physical, chemical, and biological water quality indicators to determine the location and characteristics of its treated effluent after discharge to the ocean. The goals are to assess discharge-influenced changes to water quality and compare them to criteria contained in the California Ocean Plan (COP) and the District's NPDES discharge permit to determine compliance (see box below). This chapter describes results from the July 2011 to June 2012 monitoring year. Chapter 2 (Compliance) has specific compliance evaluation details.

The District's monitoring region extends from Seal Beach to Crystal Cove State Beach, from the shoreline to approximately 12 km offshore and to a water depth of 550 m. The entire sampling area covers approximately 340 km^2 (Figure 3-1). While not part of the Core monitoring program, the District is a member of a regional cooperative sampling effort known as the Central Bight Regional Water Quality Monitoring Program (Central Bight) with the City of Oxnard, City of Los Angeles, and the Los Angeles County Sanitation District. When combined with the District's program, this additional sampling effectively extends the District's monitoring area north to Ventura County and south to Crystal Cove State Beach (Figure 3-2). The Central Bight monitoring provides regional data that enhances the evaluation of water quality changes due to natural or anthropogenic discharges (e.g., stormwater) and provides a regional context for comparisons with the District's monitoring results.

Regional and local changes in ocean conditions strongly influence the District's study area on daily, seasonal, and yearly timescales. Large-scale and long-term climatic events, such as the El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), also alter local conditions on multi-year and decadal timescales (Linacre 2010, OCSD 2004). These events are notable for producing changes in near coastal water surface temperature and rainfall/runoff in the monitoring area (OCSD 2004). One of the primary differences between ENSO and PDO is that while a typical ENSO event occurs, on average, every 5 years and may last 6–18 months (Chao et al. 2000, Mantua 2000), PDO events have cycles of 5–20 years, but may persist for up to 70 years (MacDonald and Case 2005). Upwelling can also strongly influence water quality and productivity in coastal areas by providing a source of additional nutrients to the coastal environment (Fischer et al. 1979, Sverdrup et al. 1963, Valiela 1995).

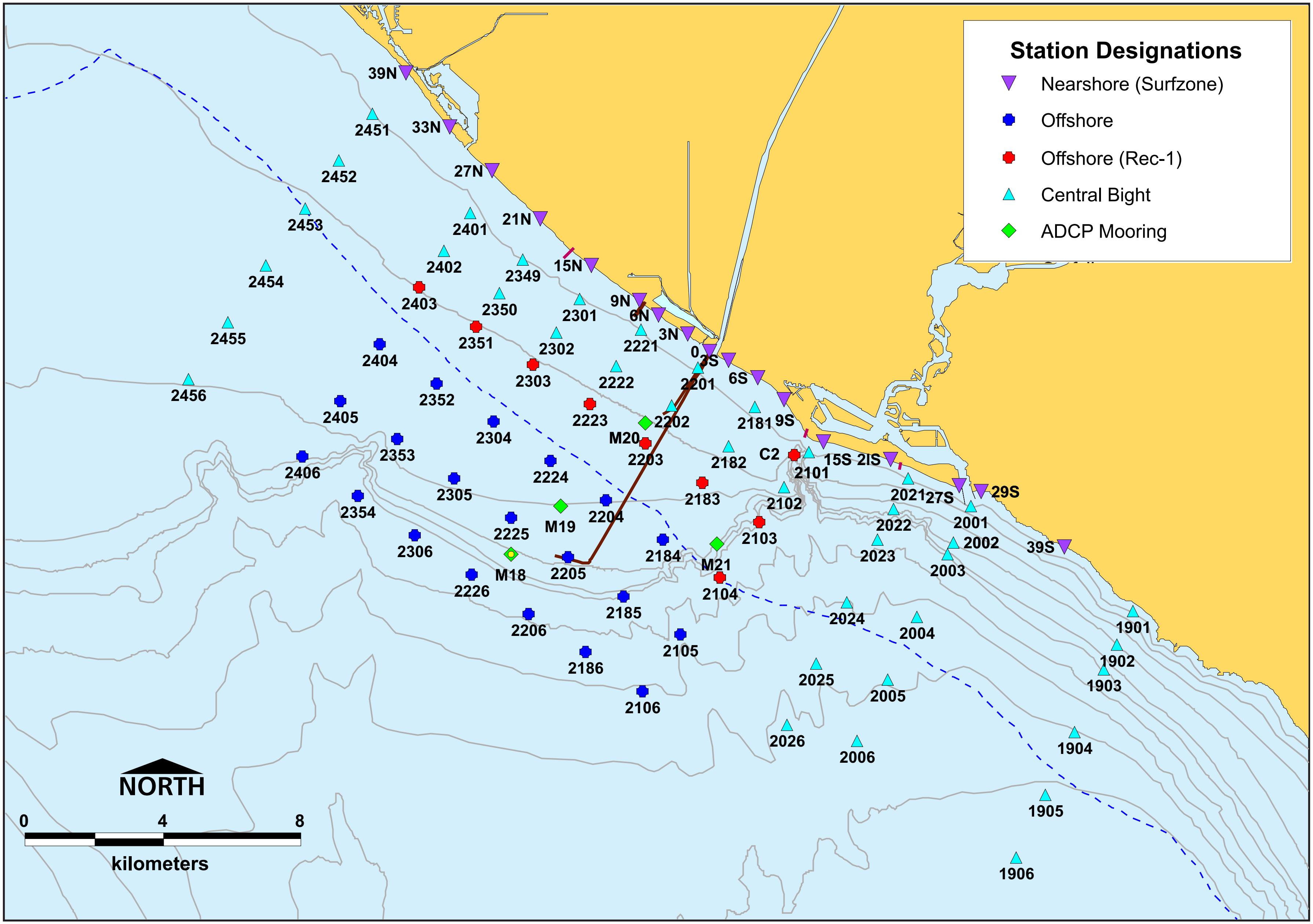


Figure 3-1. **Water quality monitoring and current meter stations for 2011-12.**

Orange County Sanitation District, California.

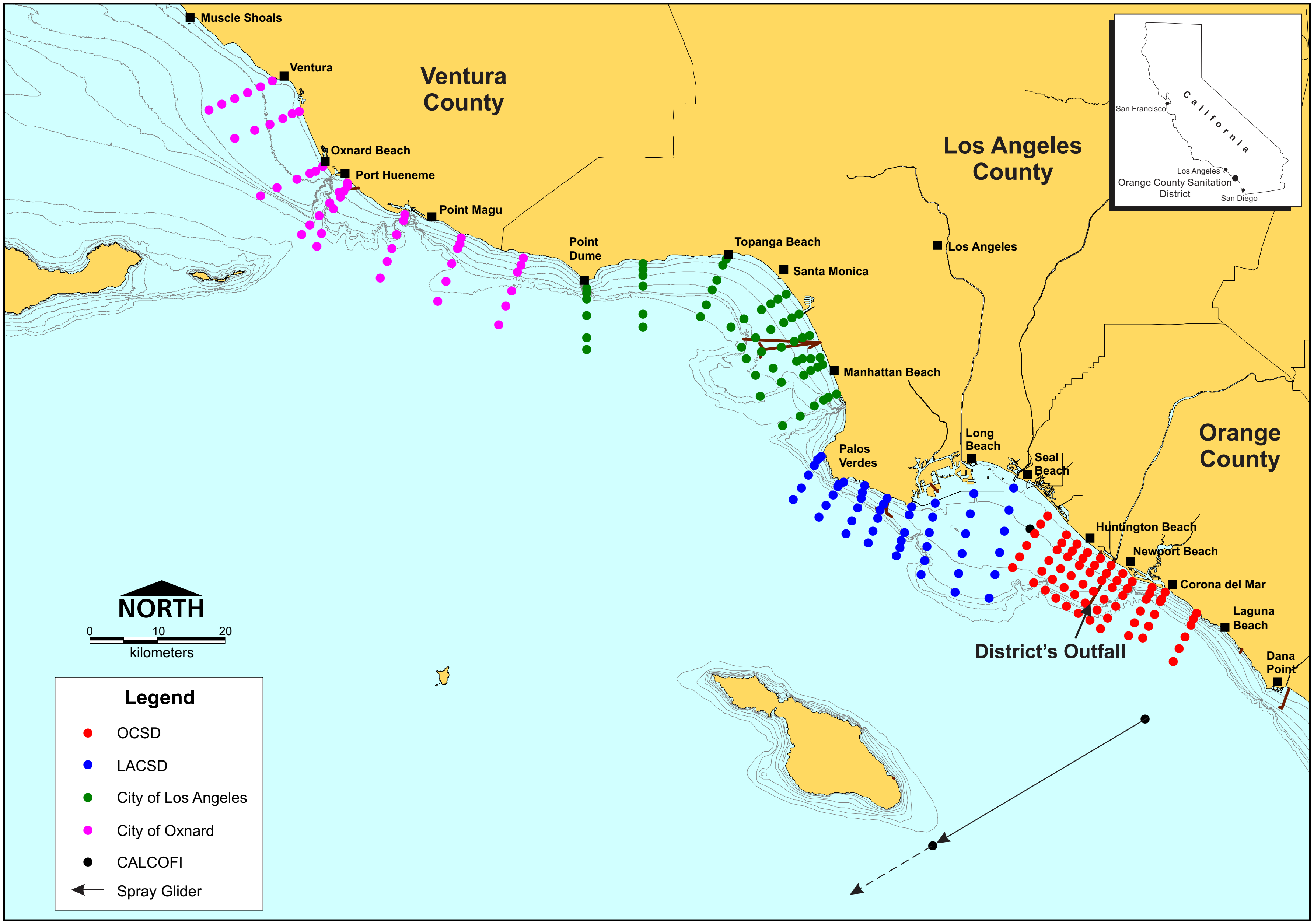


Figure 3-2. Sampling locations for the regional water quality monitoring program.

Legend denotes agencies responsible for sampling various stations. Spray glider transect extends for 500 km along CALCOFI Line 90.

Orange County Sanitation District, California.

Compliance Criteria Pertaining to Water Quality Contained in the District's NPDES Ocean Discharge Permit (Order No. R8-2004-0062, Permit No. CAO110604).		
Criteria		Description
C.2.a.1	Total coliform (water contact)	Samples of water from each sampling station shall have a density of total coliform organisms less than 1,000 per 100 ml (10 per ml); provided that not more than 20 percent of the samples at any sampling station, in any 30-day period, may exceed 1,000 per 100 ml (10 per ml), and provided further that no single sample when verified by a repeat sample taken within 48 hours shall exceed 10,000 per 100 ml (100 per ml).
C.2.a.2	Fecal coliform (water contact)	The fecal coliform density based on a minimum of not less than five samples for any 30-day period, shall not exceed a geometric mean of 200 per 100 ml nor shall more than 10 percent of the total samples during any 60-day period exceed 400 per 100 ml.
C.2.b	Shellfish harvesting standards	Within the Nearshore Zone, the following bacterial objectives shall be maintained throughout the water column: The median total coliform density shall not exceed 70 per 100 ml, and not more than 10 percent of the samples shall exceed 230 per 100 ml.
C.3.a	Floating particulates, oils and grease	Floating particulates, grease, and oil shall not be visible.
C.3.b	Water clarity and discoloration	The discharge of waste shall not cause aesthetically undesirable discoloration of the ocean surface.
C.3.c	Light transmittance	Natural light shall not be significantly reduced at any point outside the initial dilution zone as a result of the discharge of waste.
C.4.a	Dissolved oxygen	The dissolved oxygen concentration shall not at any time be depressed more than 10 percent from that which occurs naturally, as the result of the discharge of oxygen demanding waste materials.
C.4.b	Acidity (pH)	The pH shall not be changed at any time more than 0.2 units from that which occurs naturally.
C.4.f	Nutrients	Nutrient materials shall not cause objectionable aquatic growths or degrade indigenous biota.

These natural events modify anthropogenic effects, such as wastewater discharges, dredged material disposal, atmospheric deposition, and runoff from adjacent watersheds. The potential impact of climate change to the coastal ocean indicate would exacerbate human influences by altering water temperature and chemistry (e.g., salinity, dissolved oxygen, and pH), precipitation and associated runoff, and ocean circulation (Howarth, et al. 2011, Rabalaia, et al. 2010, Scavia, et al. 2002, Tynan and Opdyke 2011, Zhang, et al. 2010), which could then affect where or if a particular species may occur and in what numbers.

Wastewater discharges from the District's outfall dilute quickly by being "jetted" out through 503 discharge portholes located in the last 1.6 km of the outfall pipe. This initial dilution greatly reduces observable differences between the discharged less saline or "fresh" wastewater and seawater. Predicted changes to receiving water quality from the discharge are proportional to the ratio of wastewater mixed with seawater. The initial dilution ratio used in the District's NPDES permit is 180:1 and represents the lower 10th percentile; the mean was 352:1 (Tetra Tech 2008). Using the minimum centerline dilution of 124:1, predicted changes to receiving waters were small (Table 3-1) and fall within typical natural ranges and thereby represent low potential risks to the environment or human health.

Table 3-1. Summary of selected final effluent and receiving water parameters and expected changes compared to natural seawater at 31-45 m depths from the wastewater discharge at a minimum centerline dilution of 124:1.

Orange County Sanitation District, California.

Parameter	Final Effluent Mean	Approx. Natural Mean	Expected Change (%)	COP/AB411[1] Objectives
Temperature (°C)	25.10	11.39	Increase up to 0.11	Not Applicable
Salinity (psu)	2.25	33.46	Decrease up to 0.25	Not Applicable
Dissolved Oxygen (mg/L)	1.52	5.26	Decrease up to 0.03	<10% decrease
pH	7.20	7.91	Decrease up to 0.01	<0.2 units
Ammonia (mg/L)	30	0.2	Increase up to 0.24	Not Applicable
Total Coliform (MPN/100 mL)	27,393	0	Increase up to 219	10,000 single sample 1,000 geomean
Fecal Coliform (MPN/100 mL)	7,602	0	Increase up to 61	400 single sample 200 geomean
Enterococcus (MPN/100 mL)	783	0	Increase up to 6	104 single sample 35 geomean

[1] COP=California Ocean Plan
AB411=State of California Assembly Bill 411, enacted July 1999

Two other factors limit potential discharge effects besides initial dilution. Dynamic mixing with the ocean water and transportation away from the diffuser by prevailing ocean currents further dilutes the effluent. These currents include both large-scale ocean currents (e.g., Southern California Eddy) as well as smaller-scale local currents (Dailey et al. 1993, Noble and Xu 2004, Noble et al. 2009, OCSD 2010, SCCWRP 1973, SWRCB 1965). Additionally, natural water layering—or stratification—restricts the upward movement of the wastewater plume toward the surface; stratification off southern California is principally due to temperature (SWRCB 1965). Stratification restricts observable discharge-related changes to below 30–40 m depths during most surveys; plume rise into the upper 10 m of the water column is limited to less than 2 percent of the time (Tetra Tech 2002, 2008). These results were similar to other discharges studied by Petrenko et al. (1998) and Wu et al. (1994). Previous reports provide detailed analysis of currents (OCSD 1994; SAIC 2009, 2011), comparisons of water quality data with long-term historical trends (OCSD 1992, 1993, 1996a, b, 2004), and summaries of natural seasonal and human-related factors that affect dilution and movement of the wastewater discharge (OCSD 2004).

METHODS

Field Surveys−Core Nearshore
Collection of nearshore water samples for analysis of fecal indicator bacteria (FIB)—total and fecal coliform and enterococci—were taken at the surfzone in ankle deep water, 3–5 days per week at 17 permit-required surfzone stations (Table A-1, Figure 3-1). Three other stations, located at inlets near Bolsa Chica State Ecological Reserve (29N) and the Santa Ana River (SAR-N and SAR-S), were also sampled during the year. The occurrence and size of any grease particles at the high tide line were recorded twice a week.

Field Surveys – Core Offshore
Each quarter (summer, fall, winter, and spring), the District completed three surveys at 29 offshore stations (Table A-1, Figure 3-1). Three additional days of sampling were done at a subset of nine stations within 30 days of two of the full-scale grid sampling dates for calculating compliance with water contact (Rec-1) bacterial standards (Table A-2). During most surveys, staff collected additional bacteriological samples at outfall Station 2205 and two nearfield locations, Stations 1 and 9 (Table A-1), to better define an outfall gradient.

A Seabird© electronic sensor package (aka CTD) measured conductivity (used to calculate salinity), temperature, and depth (using pressure). Additional sensors on the package included dissolved oxygen (DO), pH, water clarity (transmissivity), chlorophyll-*a*, colored dissolved organic matter (CDOM), and photosynthetically active radiation (PAR). Data was collected 24 times/second using Seasoft (2011a) data collection software on both the downcast and upcast, from 1 m below the surface ("surface" sample) to 2 m above the bottom or to a maximum depth of 75 m. Table A-1 list the subset of stations and depths were discrete sample collection. Visual observations of water clarity (measured as Secchi-disc depth), water color (Forel/Ule), and floatable materials were also obtained at each station.

Both PAR and Secchi depth provide measures of natural light penetration through the water column. Use of a Secchi disk dates back to the mid-1800s and represents a low cost method of studying water clarity. Even though Secchi depth methodology is standardized, data quality issues remain due to the inherent problem of seeing the disk under variable lighting conditions, different readings obtained by different technicians, and the imprecision of measuring depth manually using a marked line. PAR measurements obtained using a CTD offer several advantages over Secchi disks, including the ability to obtain continuous light penetration values throughout the water column as well as standardized measures not subject to human variability (i.e., differences in eyesight).

Field Surveys−Central Bight
Each quarter, the participating Central Bight agencies sampled an expanded station grid (Table A-1, Figures 3-1 and 3-2) using similarly equipped CTDs and comparable field sampling methods. The primary differences between sampling efforts lies in the maximum depth sampled and the number of days each survey took to complete. The District samples to a maximum of 75 m, while some of the other agencies sample down to 100 m. The District did not collect discrete water samples at the Central Bight stations.

Field Surveys−Currents
Teledyne–RD Instruments acoustic Doppler current profilers (ADCP) measured ocean current speed and direction (Table A-3, Figure 3-1). Set on the ocean bottom, three ADCPs (Stations M20, M19, and M18) were located along a line parallel to the outfall and approximately perpendicular to the local bathymetry at about 20 m, 40 m, and 60 m, respectively. The fourth ADCP (Station M21) was located at 55 m water depth downcoast from the main mooring line and adjacent to the shelf break on the western flank of the Newport Canyon. Current speed and direction were taken every 6 minutes at 1 m intervals throughout the water column along with bottom water temperatures. WinSC (2003) and WinADCP (2003) were used for instrument set up and data recovery, respectively.

Data Processing and Analysis
Seasonal and annual tabular and graphic depictions of nearshore and offshore water quality data were compiled using Seasoft (2011b), IGODS (2011), Excel (2010), Deltagraph (2009), Surfer (2010), and/or SYSTAT (2009). ADCP data was processed using MATLAB (2007) routines. Offshore water quality data were grouped into five 15-meter depth bins for statistical analysis. Consistent with the method used to calculate 30-day geometric means for bacteria, non-detect values for FIBs were replaced with either 75% or 125% of the respective lower and upper detection limits (Appendix A); non-detect ammonia (NH3-N) values were handled in the same manner. Algal blooms were defined using definitions from Seubert et al. (2013).

Appendix A contains more information on the methods used for collection and analysis of the water quality data. Compliance determinations with water quality criteria are discussed in Chapter 2 (Compliance).

RESULTS AND DISCUSSION

Regional Water Quality Conditions

This section focuses on summarizing large-scale oceanographic conditions and provides quarterly comparisons for selected parameters from the regional Central Bight program and the Southern California Coastal Ocean Observation (SCCOOS) Spray glider, operated along the CalCOFI 90 line, which begins near Station1906 (Figure 3-2).

Ocean Indices
Several ocean ecosystem indices, such as the PDO, ENSO, and Upwelling Index Anomaly are indicators of ocean conditions for the California Current system. As these indices change so too do the regional ocean conditions (Figure 3-3). During 2011-12, the strongly negative PDO (-2.33 in November) indicated a continued cool phase regime that began in 2010. There was a weakening of the index into April whereupon the PDO strengthened again. Overlaid on this cool PDO regime were ENSO neutral conditions with weak La Niña conditions for most of the program year that transitioned toward El Niño conditions by May 2012. The Upwelling Anomaly Index, which represents potential productivity along the coast, was consistently positive for the year, with a late spring (May-June) peak.

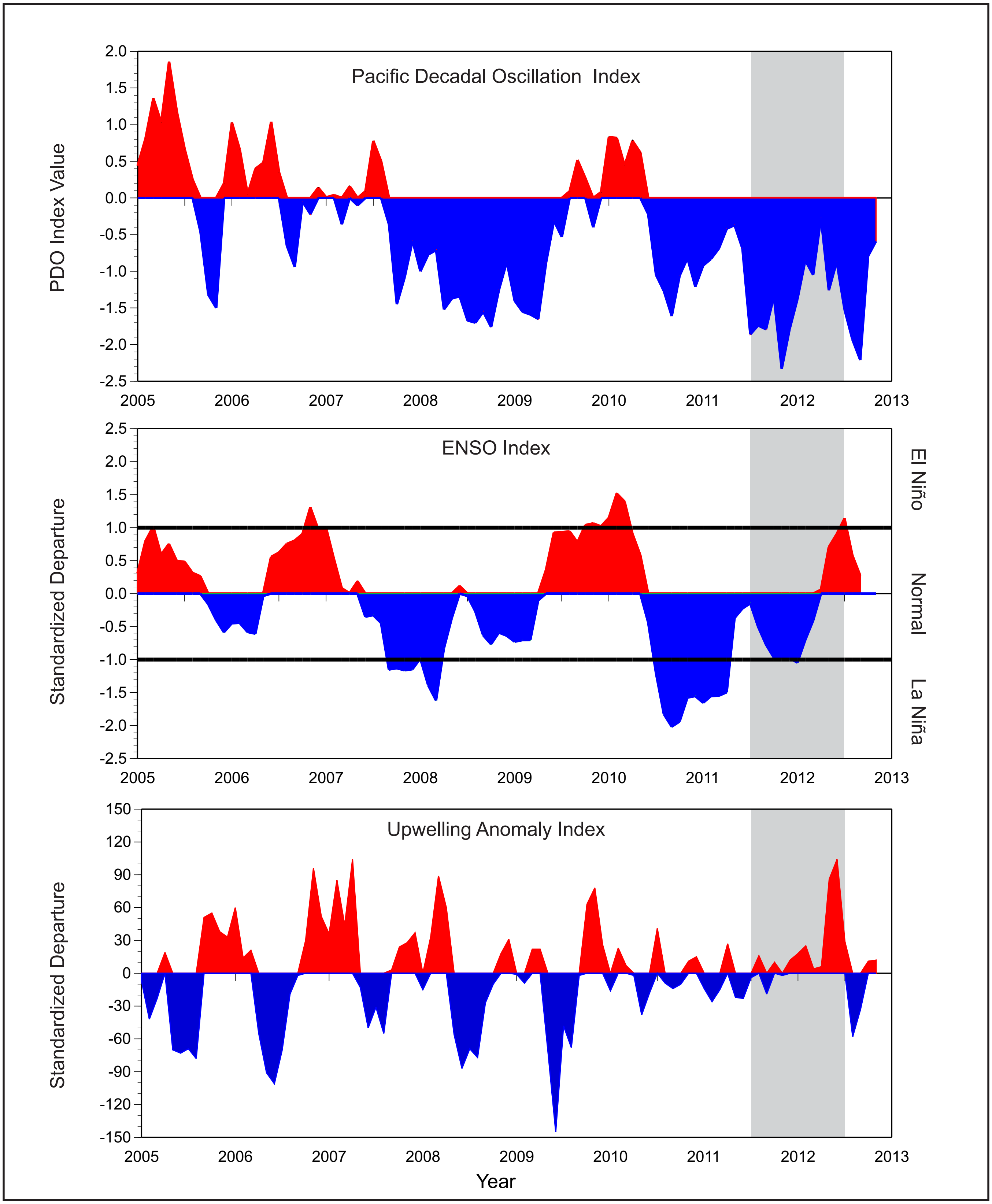


Figure 3-3. Standardized values for the Pacific Decadal Oscillation (PDO), El Niño Southern Oscillation (ENSO), and Upwelling Anomaly indices, 2005–2012.
Current program year denoted in gray.

PDO: http://jisao.washington.edu/pdo/PDO.latest
ENSO: http://www.cdc.noaa.gov/people/klaus.wolter/MEI/mei.htm
Upwelling: ftp://orpheus.pfeg.noaa.gov/outgoing/upwell/monthly/upanoms.mon

Orange County Sanitation District, California.

Regional Monitoring

Temperature

Temperature stratification was present at the Central Bight stations throughout most of the year, with most of the variability seen in the upper 30 meters of the water column. (Table 3-2, Figures 3-4, and B-2, B-3). Overall, summer waters were the warmest and had the largest temperature range. Surface waters were cooler off Ventura with several areas of much warmer water located along the inner portion of Santa Monica Bay, off the Palos Verdes Peninsula and the San Pedro Shelf. Fall temperatures dropped up to 2.5 °C in the upper 30 m and were uniform throughout the study area. Water temperatures in the upper 30 meters again cooled significantly (2-2.5 °C) in the winter, with temperatures at depths below 30 m being within ~0.5 °C of their corresponding summer and fall values. Winter temperatures were coldest off Point Dume and in the outer portion of Santa Monica Bay. Spring evidenced warming surface waters in Santa Monica Bay and on the San Pedro Shelf. Compared to the CBWQ stations as a whole, District temperature values were higher at all depths in the summer and winter and in the upper 15 m during the spring. District temperature values in the fall, and at depths greater than 15 m in the spring, were similar to regional values.

Summer temperature data from the SCCOOS Spray glider showed strong stratification near the coast in the upper 25 m, extending out nearly 200 km from the coast. This stratification lessoned in the fall, with a cooling of the surface waters and was nearly absent in the winter. Spring showed a recurrence of stratification within 200 km of the coast, consistent with observations from the southern portion of the Central Bight (Figure B-4).

Salinity

Across the Central Bight, salinity patterns changed with season and depth (Table 3-2, Figures 3-5 and B-5). A notable region-wide feature in the summer and fall was a subsurface lower (blue) salinity layer across the study area. This subarctic water is transported into the area by the California Current at water depths (30–45 m) coinciding with where wastewater plumes stabilize after mixing with receiving waters; prior to regional sampling, this layer was often misinterpreted as plume-affected water. Other local features include fresh water inputs from the Los Angeles/Long Beach Harbors throughout the year, but most notably in the summer when there was no rainfall (Table 3-2). Much reduced this year was the impact of runoff on surface salinity, most likely, due to below average rainfall observed for the year (see Figure 1-4). Spring had elevated subsurface salinities throughout the study area that reached the surface off Ventura and in Santa Monica Bay. Overall, salinities off OCSD's study area were comparable to regional values, with the exception of less saline subsurface values seen in the summer, possibly due to the presence of the subarctic water mass mentioned previously.

The summer and fall salinity SCCOOS glider data showed a relatively strong pattern of lower salinity around 50 m depth, consistent with that measured throughout the Central Bight. This subsurface layer was still evident in the winter, but was reduced from the previous two seasons. Spring salinity did not show this feature. Both summer and spring showed two areas of uplifting of the salinity isopleths at ~20 km and ~150 km offshore (Figure B-6).

Table 3-2. Summary of quarterly water quality parameters for the Central Bight Regional Water Quality Monitoring Program by season during 2011-12.

Orange County Sanitation District, California.

Depth (m)	Summer 2011				Fall 2011				Winter 2012				Spring 2012				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Temperature (°C)																				
1-15	11.87	16.82	20.46	1.95	11.63	15.46	17.92	1.11	11.90	14.07	15.36	0.68	11.22	15.68	20.67	1.51	11.22	15.49	20.67	1.69
16-30	11.06	13.68	18.31	1.28	11.13	13.31	17.02	1.15	10.78	13.38	14.76	1.01	10.34	12.90	17.06	1.21	10.34	13.31	18.31	1.20
31-45	10.55	12.17	14.22	0.64	10.77	11.66	14.26	0.54	10.36	11.93	14.05	0.82	9.99	11.20	13.77	0.59	9.99	11.73	14.26	0.75
46-60	10.08	11.35	12.68	0.49	10.35	10.99	11.86	0.23	9.97	11.09	12.63	0.50	9.83	10.45	11.51	0.28	9.83	10.96	12.68	0.51
61-75	9.78	10.54	11.87	0.42	10.11	10.59	11.19	0.18	9.56	10.49	11.46	0.40	9.66	10.02	10.76	0.18	9.56	10.41	11.87	0.39
All	9.78	13.55	20.46	2.74	10.11	12.91	17.92	2.11	9.56	12.53	15.36	1.58	9.66	12.64	20.67	2.48	9.56	12.90	20.67	2.29
Density (kg/m^3)																				
1-15	23.31	24.33	25.34	0.42	23.89	24.58	25.39	0.22	24.23	24.92	25.47	0.18	22.99	24.72	25.71	0.35	22.99	24.64	25.71	0.37
16-30	24.02	24.96	25.48	0.25	24.30	25.01	25.52	0.23	24.70	25.06	25.71	0.24	24.39	25.32	25.86	0.27	24.02	25.09	25.86	0.28
31-45	24.88	25.26	25.74	0.16	24.84	25.36	25.73	0.14	24.90	25.36	25.88	0.23	25.15	25.71	26.10	0.15	24.84	25.43	26.10	0.24
46-60	25.14	25.47	25.91	0.15	25.29	25.58	25.84	0.10	25.18	25.59	26.03	0.18	25.62	25.93	26.15	0.10	25.14	25.64	26.15	0.22
61-75	25.33	25.71	26.00	0.13	25.46	25.75	25.96	0.08	25.38	25.81	26.22	0.16	25.83	26.11	26.28	0.08	25.33	25.85	26.28	0.20
All	23.31	25.01	26.00	0.59	23.89	25.14	25.96	0.48	24.23	25.27	26.22	0.39	22.99	25.42	26.28	0.59	22.99	25.21	26.28	0.54
Salinity (psu)																				
1-15	32.98	33.41	33.57	0.06	32.77	33.34	33.58	0.06	32.77	33.38	33.54	0.06	32.90	33.58	33.77	0.06	32.77	33.43	33.77	0.11
16-30	33.14	33.33	33.52	0.06	33.11	33.30	33.46	0.04	32.94	33.38	33.61	0.08	33.44	33.59	33.78	0.06	32.94	33.40	33.78	0.13
31-45	33.08	33.32	33.56	0.07	33.16	33.34	33.60	0.07	32.98	33.41	33.71	0.12	33.52	33.68	33.91	0.07	32.98	33.44	33.91	0.17
46-60	33.17	33.40	33.68	0.09	33.26	33.46	33.75	0.09	33.01	33.50	33.82	0.13	33.63	33.79	33.96	0.07	33.01	33.54	33.96	0.18
61-75	33.29	33.53	33.75	0.08	33.36	33.59	33.81	0.08	33.13	33.64	33.97	0.12	33.73	33.92	34.06	0.07	33.13	33.67	34.06	0.17
All	32.98	33.40	33.75	0.10	32.77	33.39	33.81	0.13	32.77	33.45	33.97	0.14	32.90	33.69	34.06	0.15	32.77	33.48	34.06	0.18
Dissolved Oxygen (mg/L)																				
1-15	5.73	8.01	9.52	0.65	5.52	7.74	10.26	0.70	5.56	8.09	9.59	0.53	4.08	8.24	10.43	1.06	4.08	8.02	10.43	0.79
16-30	4.96	7.34	9.03	0.63	5.23	6.97	10.05	0.82	4.25	6.99	8.81	1.12	3.11	6.47	10.32	1.46	3.11	6.92	10.32	1.12
31-45	4.74	6.54	8.07	0.65	4.67	5.96	7.81	0.52	3.63	5.42	7.68	0.78	2.43	4.25	8.23	0.93	2.43	5.47	8.23	1.11
46-60	4.30	5.80	7.06	0.60	3.86	5.18	6.68	0.46	3.22	4.75	6.12	0.59	2.41	3.28	5.09	0.47	2.41	4.68	7.06	1.06
61-75	3.88	5.14	6.39	0.46	3.26	4.43	5.87	0.51	2.90	4.16	5.39	0.51	2.02	2.73	4.11	0.31	2.02	4.01	6.39	0.97
All	3.88	6.89	9.52	1.21	3.26	6.35	10.26	1.40	2.90	6.27	9.59	1.70	2.02	5.56	10.43	2.40	2.02	6.22	10.43	1.83

Table 3-2 continues.

Table 3-2 continued.

Depth (m)	Summer 2011				Fall 2011				Winter 2012				Spring 2012				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Dissolved Oxygen Saturation (%)																				
1-15	70.32	100.47	118.59	8.42	62.69	95.10	127.96	9.77	64.32	96.67	115.48	7.30	47.11	101.96	127.67	14.64	47.11	98.44	127.96	10.89
16-30	55.59	86.85	109.56	9.04	58.89	82.12	121.44	11.10	47.50	82.55	106.11	14.55	34.97	75.99	126.09	18.97	34.97	81.53	126.09	14.70
31-45	53.08	75.15	96.35	8.29	52.36	67.72	91.47	6.42	40.27	62.06	91.73	9.89	26.99	48.00	97.89	11.13	26.99	62.43	97.89	13.38
46-60	47.48	65.48	81.83	7.33	43.17	58.11	75.70	5.34	35.41	53.38	71.00	7.13	26.53	36.49	57.58	5.36	26.53	52.52	81.83	12.24
61-75	42.69	57.11	72.93	5.47	36.52	49.25	65.72	5.74	31.66	46.27	60.38	5.94	22.16	30.05	45.38	3.50	22.16	44.47	72.93	10.93
All	42.69	81.96	118.59	17.85	36.52	74.75	127.96	19.28	31.66	73.16	115.48	21.93	22.16	66.00	127.67	31.41	22.16	73.39	127.96	24.19
Chlorophyll-*a* (µg/L)																				
1-15	0.44	4.61	23.62	3.21	0.45	6.50	35.75	5.82	0.25	1.87	10.43	1.75	0.22	3.52	47.48	4.75	0.22	4.16	47.48	4.51
16-30	1.10	5.63	17.36	2.17	0.97	4.75	21.04	2.75	0.40	1.83	7.94	1.22	0.23	5.72	40.42	6.38	0.23	4.40	40.42	3.87
31-45	0.52	3.79	9.87	1.71	0.70	2.19	7.34	0.99	0.36	1.03	5.37	0.63	0.09	2.18	23.04	2.71	0.09	2.27	23.04	1.92
46-60	0.27	2.23	5.32	1.12	0.35	1.18	3.68	0.60	0.21	0.49	2.62	0.21	0.09	0.63	5.84	0.71	0.09	1.14	5.84	1.00
61-75	0.25	1.06	3.78	0.65	0.24	0.70	2.70	0.43	0.08	0.23	0.91	0.10	0.06	0.21	1.23	0.16	0.06	0.56	3.78	0.53
All	0.25	3.77	23.62	2.75	0.24	3.68	35.75	4.21	0.08	1.25	10.43	1.34	0.06	2.87	47.48	4.62	0.06	2.87	47.48	3.57
pH (pH units)																				
1-15	7.90	8.13	8.31	0.07	7.89	8.18	8.36	0.08	7.81	8.10	8.26	0.09	7.89	8.16	8.29	0.06	7.81	8.14	8.36	0.08
16-30	7.84	8.04	8.27	0.10	7.85	8.10	8.26	0.08	7.74	8.04	8.20	0.09	7.63	8.03	8.26	0.11	7.63	8.06	8.27	0.10
31-45	7.76	7.96	8.20	0.09	7.83	8.03	8.18	0.08	7.67	7.91	8.10	0.07	7.57	7.88	8.14	0.14	7.57	7.94	8.20	0.11
46-60	7.70	7.90	8.09	0.09	7.78	7.96	8.15	0.08	7.59	7.84	7.97	0.06	7.55	7.79	8.05	0.14	7.55	7.87	8.15	0.12
61-75	7.67	7.86	8.06	0.08	7.72	7.87	8.08	0.08	7.53	7.78	7.91	0.07	7.53	7.74	8.00	0.10	7.53	7.81	8.08	0.10
All	7.67	8.00	8.31	0.13	7.72	8.06	8.36	0.14	7.53	7.96	8.26	0.15	7.53	7.96	8.29	0.20	7.53	8.00	8.36	0.16
Light Transmission (%)																				
1-15	27.61	81.78	88.69	5.55	48.91	81.92	88.71	6.67	21.61	82.81	89.35	5.94	27.63	81.22	88.35	4.80	21.61	81.93	89.35	5.81
16-30	56.54	85.53	89.02	2.34	49.45	85.49	89.53	3.64	31.36	84.97	89.53	4.00	40.96	82.37	89.60	4.61	31.36	84.57	89.60	3.98
31-45	76.06	86.99	89.51	1.54	79.35	87.65	89.91	1.51	71.39	87.06	89.84	1.95	60.90	85.82	90.39	3.15	60.90	86.88	90.39	2.26
46-60	73.73	87.06	89.83	2.05	79.05	87.95	90.29	1.59	74.85	87.78	89.75	1.63	77.29	87.18	90.47	2.53	73.73	87.50	90.47	2.02
61-75	79.43	88.01	90.16	1.62	84.37	88.64	90.42	0.96	81.55	88.72	90.29	1.15	80.26	88.13	90.59	2.08	79.43	88.38	90.59	1.55
All	27.61	85.24	90.16	4.26	48.91	85.63	90.42	4.97	21.61	85.69	90.29	4.54	27.63	84.23	90.59	4.77	21.61	85.20	90.59	4.69

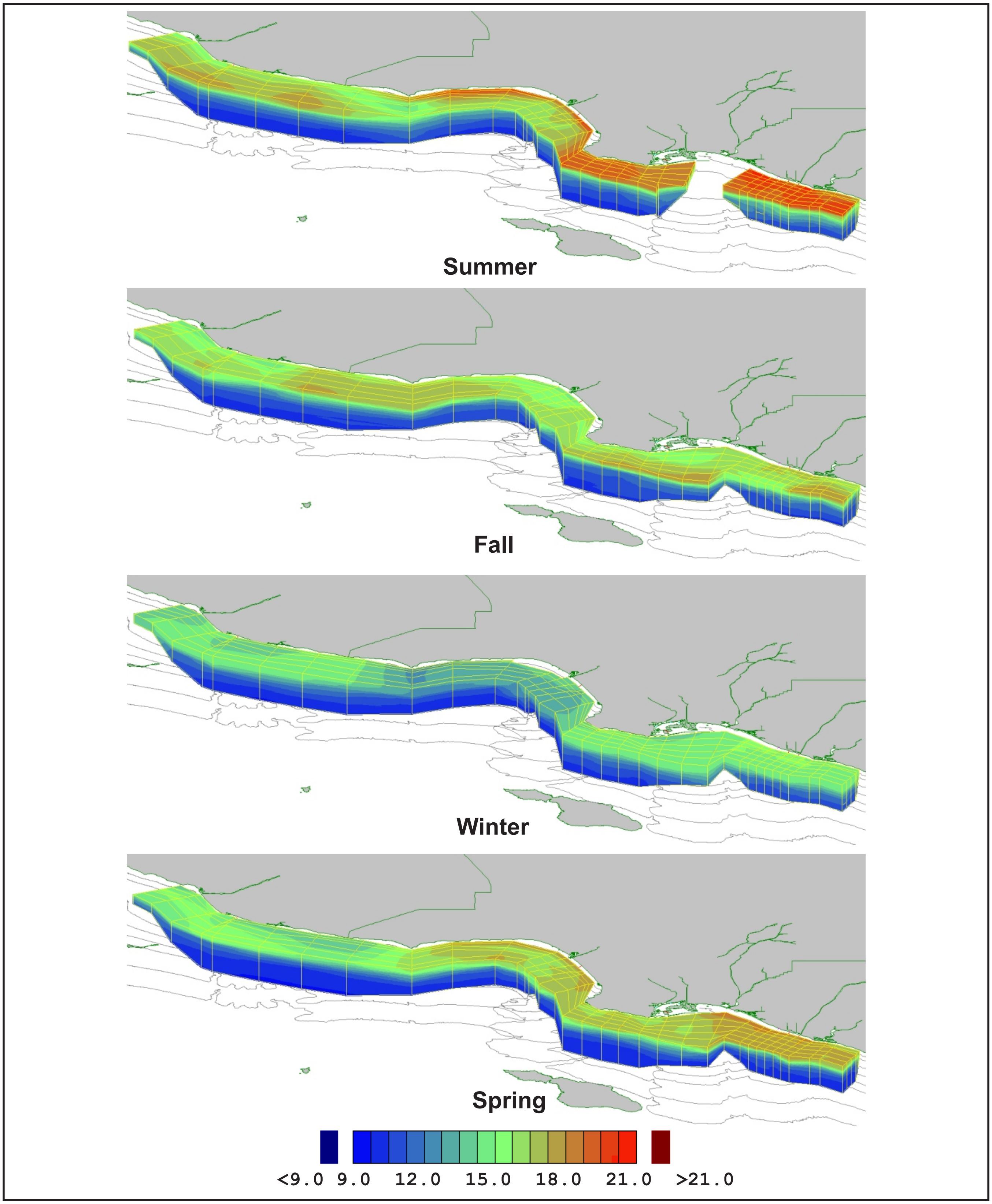


Figure 3-4. **Seasonal patterns of temperature (°C) for summer (August 2011), fall (November 2011), winter (February 2012), and spring (May 2012) for the Central Bight Regional Water Quality Monitoring Program grid.**

Orange County Sanitation District, California.

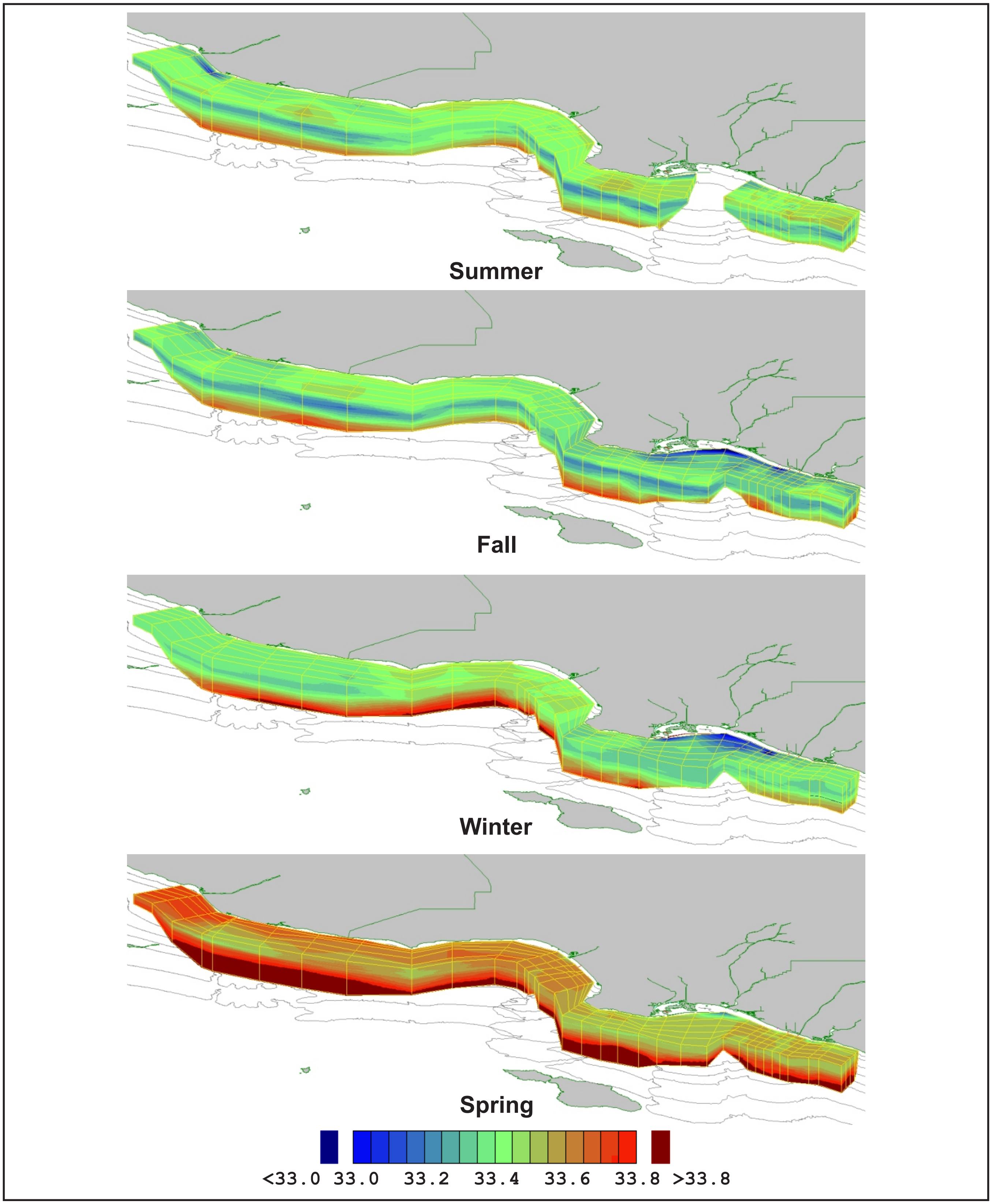


Figure 3-5. **Seasonal patterns of salinity (psu) for summer (August 2011), fall (November 2011), winter (February 2012), and spring (May 2012) for the Central Bight Regional Water Quality Monitoring Program grid.**

Orange County Sanitation District, California.

Dissolved Oxygen

Central Bight, dissolved oxygen (DO) values ranged from 2–10.4 mg/L, with the extremes occurring in the spring (Table 3-2, Figures 3-6, B-7, and B-8). Except for spring at depths below 45 m, all DO values were above levels considered stressful (OCSD 1995) or hypoxic (USGS 2006). Strong gradients were present throughout the water column each season with depth differences of 5.6–8.4 mg/L from surface to bottom. Values greater than 10 mg/L were seen in the upper 30 m in the fall and spring, with the lowest values seen below 30 m in the spring. The high fall and spring DO values were associated with times of higher productivity as evidenced by chlorophyll-*a* (see section below). Values within the District's study area were typically higher at depths below 15 m in the summer, fall, and winter seasons. Surface values in the summer were lower than regional values. Spring values were comparable to regional measurements.

Chlorophyll-*a*

Chlorophyll-*a,* used as a surrogate for phytoplankton biomass, varied widely, both seasonally and regionally in the Central Bight (Figures 3-7 and B-9). Typically, both the maximum values and widest range occur in the spring, but fall saw significant areas of elevated chlorophyll off Ventura and on the San Pedro shelf. Summer chlorophyll was also elevated with a regional subsurface maximum evident. Overall, there was a 45% reduction from the previous year in the annual mean chlorophyll. Seasonally these reductions were 38% (summer); 16% (fall); 70% (winter); and 54% (spring). District chlorophyll values were comparable to regional values in the summer and fall, but below regional measures in the winter and spring. Regionally, chlorophyll blooms were noted in both the fall and spring, however, within the District's study area, blooms occurred principally in the fall (Table 3-3).

The SCCOOS glider chlorophyll-*a* sensor was not calibrated so seasonal comparisons of concentration could not be done. However, within a season, comparison of relative strengths and spatial patterns were considered valid. Summer data showed elevated subsurface chlorophyll (down to 50 m), consistent with CBWQ results. Fall data showed continued subsurface maximum that rose to the surface near the coast, which matched CBWQ results of maximum values at the surface, particularly on the San Pedro shelf. Winter data did not show any strong features in the upper 50 m of the water column past 100 km from shore. Spring shoed a reoccurrence of elevated subsurface values, which was seen in the CBWQ data off Santa Monica Bay, but not off the San Pedro shelf (Figure B-10).

Regional scatter plots of pH and transmissivity (%T) (Figures B-11 and B-12) are included with the data but are not discussed in this report

Local Water Quality Conditions

This section focuses on data collected for both the Nearshore (surfzone) and Offshore sampling programs, and includes seasonal comparisons and determinations of plume impacts.

Nearshore (Surfzone) Bacteria

While the surfzone bacteria counts varied by season, location along the coast, and by indicator bacteria type, a general spatial pattern was associated with the mouth of the Santa Ana River. (Table 3-4, Figures 3-8 and 3-9). Seasonal geomeans (Figure 3-8) and

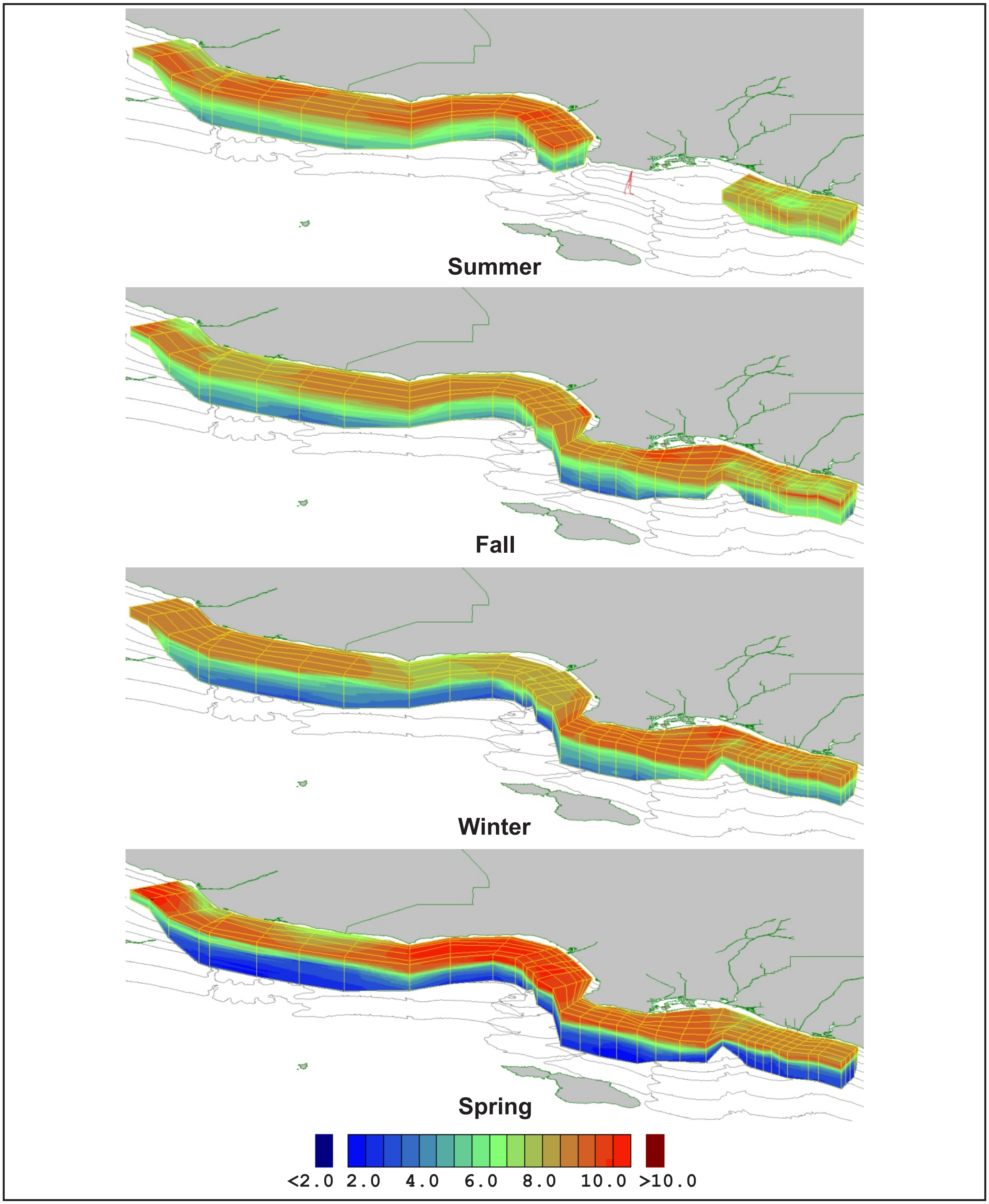


Figure 3-6. **Seasonal patterns of dissolved oxygen (mg/L) for summer (August 2011), fall (November 2011), winter (February 2012), and spring (May 2012) for the Central Bight Regional Water Quality Monitoring Program grid.**

Orange County Sanitation District, California.

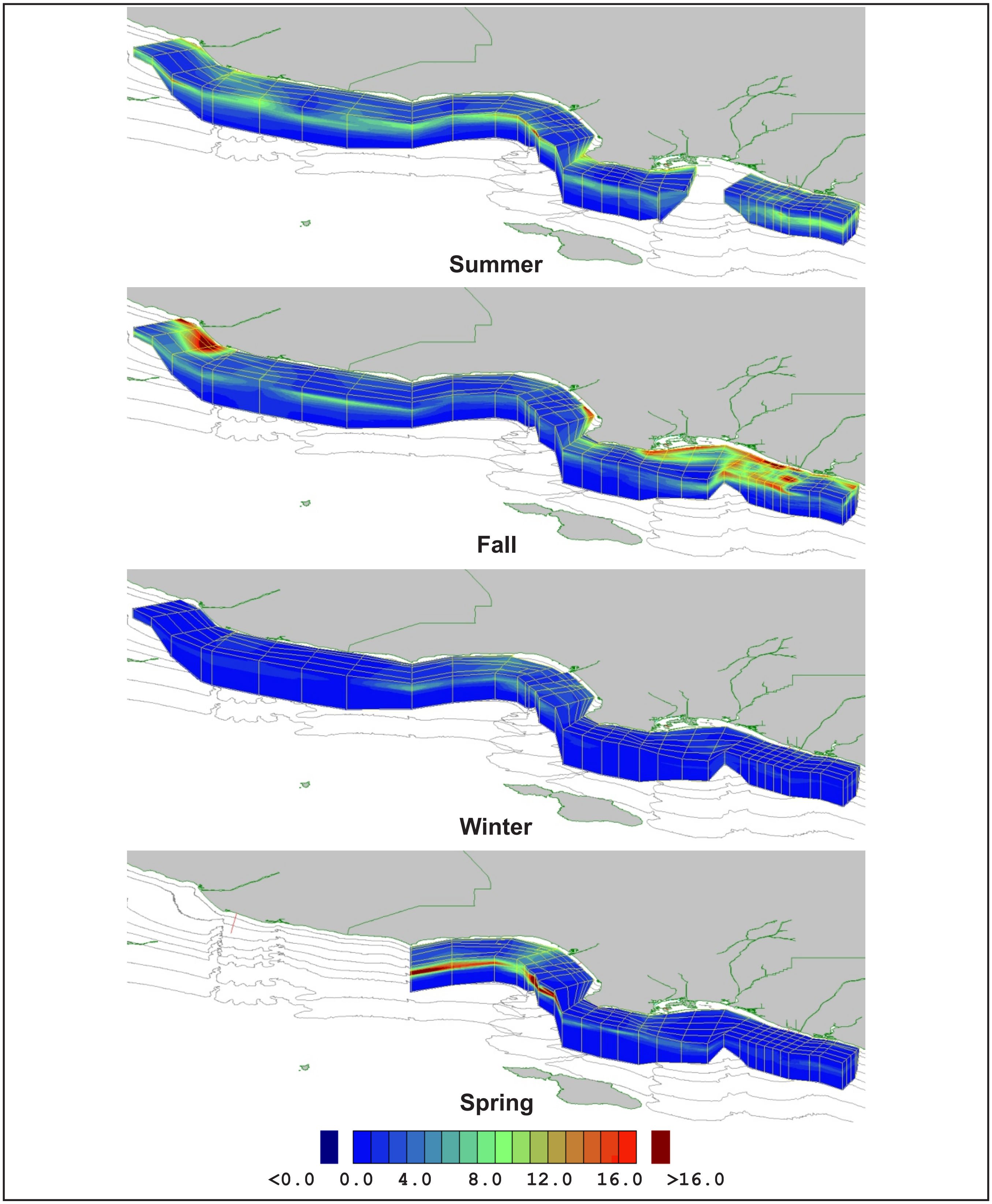


Figure 3-7. **Seasonal patterns of chlorophyll-*a* (µg/L) for summer (August 2011), fall (November 2011), winter (February 2012), and spring (May 2012) for the Central Bight Regional Water Quality Monitoring Program grid.**

Orange County Sanitation District, California.

Table 3-3. Chlorophyll bloom determinations by percent for quarterly regional sampling, July 2011 through June 2012.

Orange County Sanitation District, California.

Date	No Bloom	Minor Bloom	Major Bloom
OCSD only			
Summer 2011	96.0%	3.3%	0.7%
Fall 2011	77.4%	10.6%	12.0%
Winter 2012	100.0%	0.0%	0.0%
Spring 2012	100.0%	0.0%	0.0%
Annual (2011-12)	93.4%	3.5%	3.2%
Regional stations (excluding OCSD)			
Summer 2011	96.0%	2.5%	1.5%
Fall 2011	90.3%	2.0%	7.7%
Winter 2012	98.6%	0.9%	0.5%
Spring 2012	91.9%	3.0%	5.2%
Annual (2011-12)	94.2%	2.1%	3.7%
Regional stations (including OCSD)			
Summer 2011	96.0%	2.7%	1.3%
Fall 2011	87.7%	3.7%	8.5%
Winter 2012	98.9%	0.7%	0.4%
Spring 2012	93.5%	2.4%	4.1%
Annual (2011-12)	94.0%	2.4%	3.6%

Table 3-4. **Summary statistics for surf zone total coliform, fecal coliform, and enterococcus bacteria (MPN/100 mL) by station and seasons during 2011-12.**

Orange County Sanitation District, California.

Station	Summer				Fall				Winter				Spring				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Total Coliform																				
39N	<18	19.79	110	1.88	<18	39.61	20,000	4.12	<18	18.27	700	1.91	<18	15.53	270	1.51	<18	21.53	20,000	2.51
33N	<18	19.49	150	1.86	<18	39.96	17,500	4.13	<18	21.63	760	2.18	<18	20.00	740	2.06	<18	23.88	17,500	2.63
27N	<18	20.35	620	2.15	<18	37.20	23,750	4.47	<18	19.13	620	2.15	<18	18.19	700	1.88	<18	22.49	23,750	2.72
21N	<18	19.88	5,400	2.50	<18	24.16	1,200	2.86	<18	24.72	560	2.57	<18	16.82	880	1.89	<18	21.05	5,400	2.47
15N	<18	25.06	19,000	3.11	<18	31.67	700	3.11	<18	35.08	1,500	3.13	<18	18.34	16,250	2.56	<18	26.57	19,000	3.04
12N	<18	26.76	39,000	3.57	<18	39.42	1,175	3.33	<18	35.62	4,200	3.31	<18	21.78	18,750	2.96	<18	29.85	39,000	3.34
9N	<18	29.10	21,000	3.57	<18	39.09	5,200	3.85	<18	31.69	4,800	3.09	<18	26.04	46,250	3.80	<18	30.97	46,250	3.59
6N	<18	31.27	16,000	4.43	<18	44.93	6,400	3.84	<18	65.28	24,000	5.66	<18	24.75	4,400	3.04	<18	38.54	24,000	4.38
3N	<18	25.74	11,000	3.16	<18	39.63	6,800	3.67	<18	36.83	4,000	3.41	<18	48.16	14,000	5.41	<18	36.48	14,000	3.93
0	<18	22.98	1,200	2.71	<18	38.92	32,000	4.35	<18	64.24	13,000	5.94	<18	28.94	27,500	4.35	<18	35.60	32,000	4.47
SAR-N	<18	20.28	1,400	2.23	<18	43.72	67,000	6.42	<18	48.92	5,200	4.56	<18	29.77	2,600	3.40	<18	33.12	67,000	4.14
SAR-S	<18	122.50	4,200	5.13	<18	132.96	113,750	8.32	<18	172.32	15,000	7.36	<18	659.10	50,000	7.97	<18	209.59	113,750	7.88
3S	<18	17.56	5,000	2.26	<18	28.48	28,000	3.78	<18	41.53	5,800	4.00	<18	21.89	14,000	3.21	<18	25.70	28,000	3.40
6S	<18	15.25	5,600	2.10	<18	27.17	18,750	4.23	<18	37.96	7,800	3.95	<18	17.48	1,100	1.91	<18	22.67	18,750	3.17
9S	<18	17.95	5,200	2.55	<18	29.37	18,750	4.50	<18	27.16	1,500	3.04	<18	15.44	91	1.38	<18	21.51	18,750	2.93
15S	<18	18.08	1,100	2.14	<18	27.77	17,500	4.16	<18	29.55	1,750	2.82	<18	15.90	73	1.43	<18	21.87	17,500	2.71
21S	<18	15.95	150	1.52	<18	22.66	6,600	3.66	<18	30.29	1,250	3.01	<18	16.92	720	1.83	<18	20.61	6,600	2.57
27S	<18	14.22	18	1.12	<18	18.53	5,200	3.06	<18	22.56	2,400	3.01	<18	14.25	18	1.12	<18	16.97	5,200	2.22
29S	<18	26.65	150	1.96	<18	30.35	5,400	3.33	<18	32.94	1,875	3.04	<18	22.08	400	2.21	<18	27.61	5,400	2.64
39S	<18	16.04	580	1.66	<18	20.38	290	2.21	<18	15.90	800	1.78	<18	16.41	440	1.89	<18	17.04	800	1.90
All	<18	22.85	39,000	2.87	<18	34.42	113,750	4.18	<18	34.85	24,000	3.88	<18	24.62	50,000	3.69	<18	28.47	113,750	3.68

Table 3-4 continues.

Table 3-4 Continued.

Station	Summer				Fall				Winter				Spring				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Fecal Coliform																				
39N	<18	17.75	73	1.56	<18	19.45	980	2.09	<18	15.52	55	1.33	<18	14.49	36	1.21	<18	16.67	980	1.60
33N	<18	19.05	73	1.64	<18	19.83	760	2.17	<18	17.86	150	1.72	<18	16.21	580	1.75	<18	18.17	760	1.82
27N	<18	16.98	440	1.80	<18	17.43	940	2.10	<18	16.45	440	1.68	<18	15.88	160	1.52	<18	16.67	940	1.77
21N	<18	15.86	350	1.63	<18	17.69	1,100	1.93	<18	17.70	330	1.70	<18	14.73	180	1.40	<18	16.41	1,100	1.67
15N	<18	20.42	4,800	2.40	<18	20.13	1,500	2.19	<18	23.44	1,300	2.25	<18	15.89	91	1.46	<18	19.76	4,800	2.11
12N	<18	19.11	6,000	2.35	<18	26.88	1,300	2.62	<18	24.42	160	2.05	<18	18.15	180	1.84	<18	21.73	6,000	2.24
9N	<18	22.06	17,000	2.83	<18	22.51	2,900	2.47	<18	21.42	200	2.00	<18	20.46	600	2.40	<18	21.59	17,000	2.43
6N	<18	26.23	1,700	3.14	<18	26.46	1,000	2.64	<18	43.34	12,000	4.73	<18	21.31	500	2.35	<18	28.21	12,000	3.26
3N	<18	20.17	700	2.12	<18	19.02	1,100	2.19	<18	24.15	460	2.23	<18	37.46	14,000	4.78	<18	24.33	14,000	2.90
0	<18	19.49	760	2.28	<18	19.44	6,800	2.58	<18	31.31	1,200	3.23	<18	24.25	4,200	3.27	<18	23.14	6,800	2.88
SAR-N	<18	16.82	130	1.63	<18	25.32	25,000	4.18	<18	34.24	5,000	3.63	<18	25.05	4,000	3.60	<18	24.43	25,000	3.29
SAR-S	<18	85.07	2,300	5.10	<18	77.19	30,000	7.18	<18	88.93	7,600	6.77	<18	417.53	13,000	7.73	<18	125.52	30,000	7.44
3S	<18	15.54	250	1.58	<18	19.48	1,500	2.48	<18	29.17	2,000	2.63	<18	17.37	720	2.01	<18	19.70	2,000	2.25
6S	<18	14.80	250	1.45	<18	17.41	1,100	2.02	<18	22.54	1,100	2.44	<18	15.28	130	1.45	<18	17.20	1,100	1.89
9S	<18	15.67	620	1.87	<18	17.41	1,100	2.06	<18	18.11	150	1.71	<18	14.71	73	1.35	<18	16.38	1,100	1.77
15S	<18	14.75	150	1.42	<18	18.92	1,100	2.17	<18	21.95	250	2.12	<18	14.27	55	1.25	<18	17.11	1,100	1.81
21S	<18	15.13	55	1.32	<18	17.44	600	2.27	<18	21.68	780	2.28	<18	14.88	130	1.40	<18	17.03	780	1.87
27S	<18	14.58	55	1.28	<18	16.77	760	2.03	<18	17.68	1,800	2.18	<18	14.24	55	1.21	<18	15.71	1,800	1.73
29S	<18	18.98	91	1.68	<18	21.17	880	2.49	<18	24.87	440	2.38	<18	17.54	130	1.66	<18	20.40	880	2.07
39S	<18	14.81	310	1.50	<18	14.94	110	1.39	<18	14.26	36	1.21	<18	14.46	130	1.37	<18	14.61	310	1.37
All	<18	19.16	17,000	2.28	<18	20.99	30,000	2.66	<18	24.02	12,000	2.72	<18	20.70	14,000	2.97	<18	21.12	30,000	2.66

Table 3-4 continues.

Table 3-4 Continued.

Station	Summer				Fall				Winter				Spring				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Enterococcus																				
39N	<2	7.03	94	3.39	<2	5.49	210	3.26	<2	4.19	>400	2.81	<2	2.86	172	2.86	<2	4.65	>400	3.22
33N	<2	8.75	80	2.95	<2	10.72	372	3.81	<2	5.84	>400	3.20	<2	4.37	84	2.76	<2	6.97	>400	3.31
27N	<2	6.65	34	2.72	<2	8.75	380	3.93	<2	9.41	>400	3.58	<2	5.65	>400	3.32	<2	7.42	>400	3.40
21N	<2	5.86	126	3.01	<2	5.89	346	3.25	<2	14.02	>400	4.21	<2	3.40	72	2.73	<2	6.33	>400	3.62
15N	<2	6.59	60	3.14	<2	7.59	362	3.50	<2	16.44	>400	3.66	<2	3.94	84	2.84	<2	7.49	>400	3.62
12N	<2	6.21	>400	3.46	<2	7.73	372	4.00	<2	15.85	164	3.42	<2	4.37	>400	3.34	<2	7.53	>400	3.83
9N	<2	7.02	356	3.62	<2	7.54	344	3.55	<2	11.23	334	3.73	<2	4.81	>400	3.38	<2	7.28	>400	3.68
6N	<2	7.47	>400	4.35	<2	12.50	>400	4.44	<2	20.79	>400	3.89	<2	5.99	286	3.58	<2	10.27	>400	4.37
3N	<2	4.70	156	3.16	<2	5.77	198	3.41	<2	12.15	>400	3.49	<2	13.76	>400	5.76	<2	8.19	>400	4.21
0	<2	3.08	108	2.48	<2	4.73	>400	3.18	<2	12.34	>400	4.37	<2	6.32	>400	3.93	<2	5.76	>400	3.81
SAR-N	<2	3.12	216	2.83	<2	5.82	>400	5.05	<2	12.21	>400	3.86	<2	6.39	>400	4.02	<2	6.07	>400	4.21
SAR-S	<2	28.76	>400	5.98	<2	21.66	>400	7.50	<2	22.04	>400	4.52	<2	67.50	>400	4.65	<2	31.27	>400	5.89
3S	<2	2.82	148	2.65	<2	4.17	>400	3.60	<2	13.97	>400	4.50	<2	3.71	30	2.74	<2	4.92	>400	3.85
6S	<2	2.77	24	2.16	<2	3.60	320	2.95	<2	7.39	>400	3.94	<2	2.89	56	2.38	<2	3.80	>400	3.03
9S	<2	2.45	180	2.21	<2	4.34	332	3.53	<2	5.77	68	3.11	<2	2.41	28	2.12	<2	3.45	332	2.90
15S	<2	3.03	72	2.47	<2	4.16	298	3.37	<2	4.82	104	3.31	<2	2.36	98	2.41	<2	3.44	298	2.96
21S	<2	2.32	24	1.82	<2	3.08	392	3.37	<2	6.04	124	4.03	<2	2.53	24	2.15	<2	3.21	392	2.99
27S	<2	2.08	10	1.68	<2	2.51	370	2.87	<2	3.78	>400	3.89	<2	2.02	16	1.78	<2	2.50	>400	2.62
29S	<2	5.21	84	3.28	<2	4.19	122	3.40	<2	5.30	270	3.41	<2	4.63	124	3.11	<2	4.82	270	3.29
39S	<2	2.61	68	2.36	<2	3.12	>400	4.12	<2	1.79	6	1.42	<2	2.53	160	2.60	<2	2.46	>400	2.66
All	<2	4.68	>400	3.45	<2	5.77	>400	4.05	<2	8.85	>400	4.16	<2	4.66	>400	3.88	<2	5.75	>400	3.97

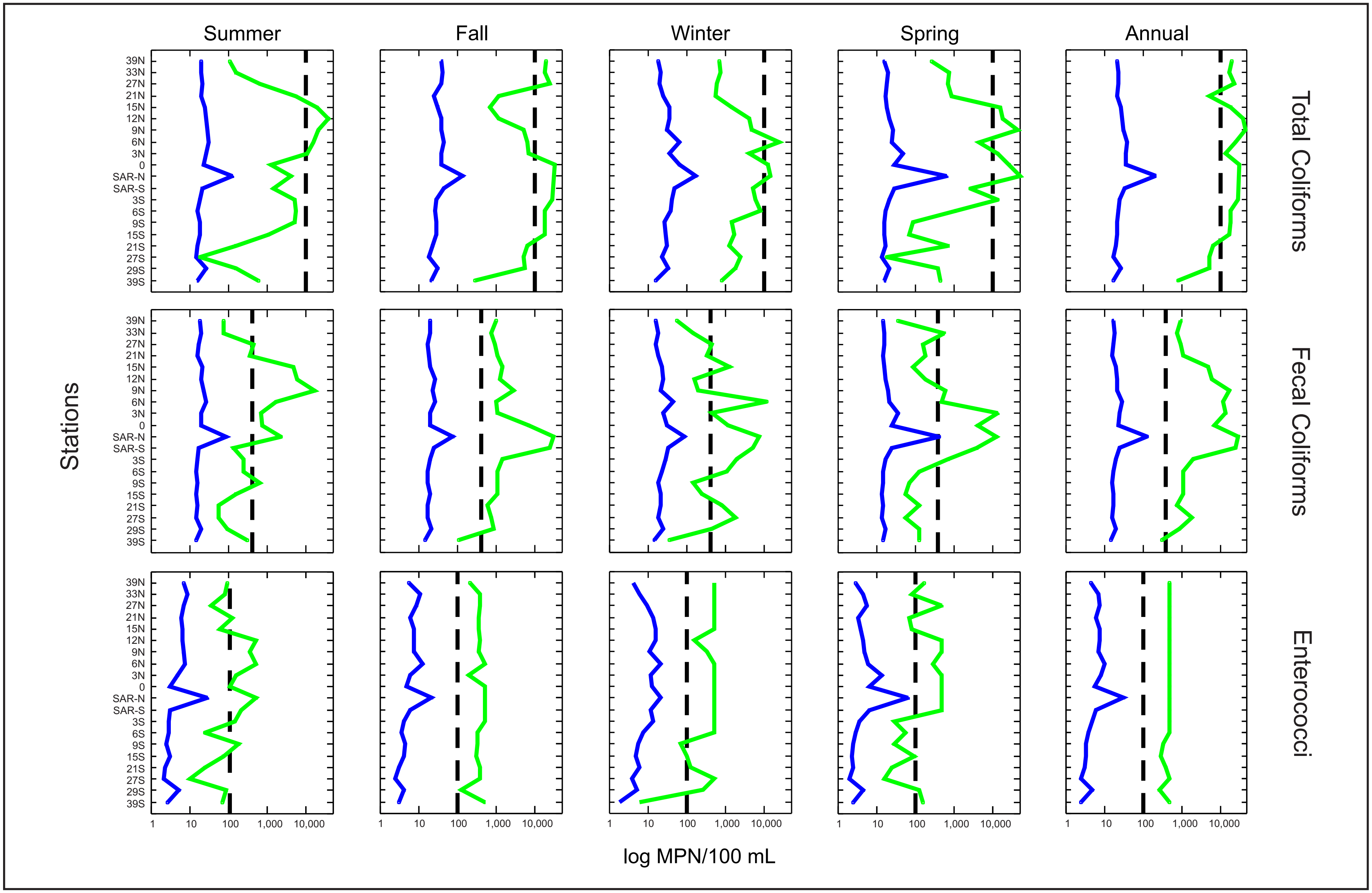


Figure 3-8. Seasonal distribution of total coliform, fecal coliform, and enterococci bacteria at the District's nearshore (surfzone) water quality stations for July 1, 2011 to June 30, 2012.

Blue line = geometric mean for the season, green line = maximum value during the season, dashed vertical line = single sample limit.

Orange County Sanitation District, California.

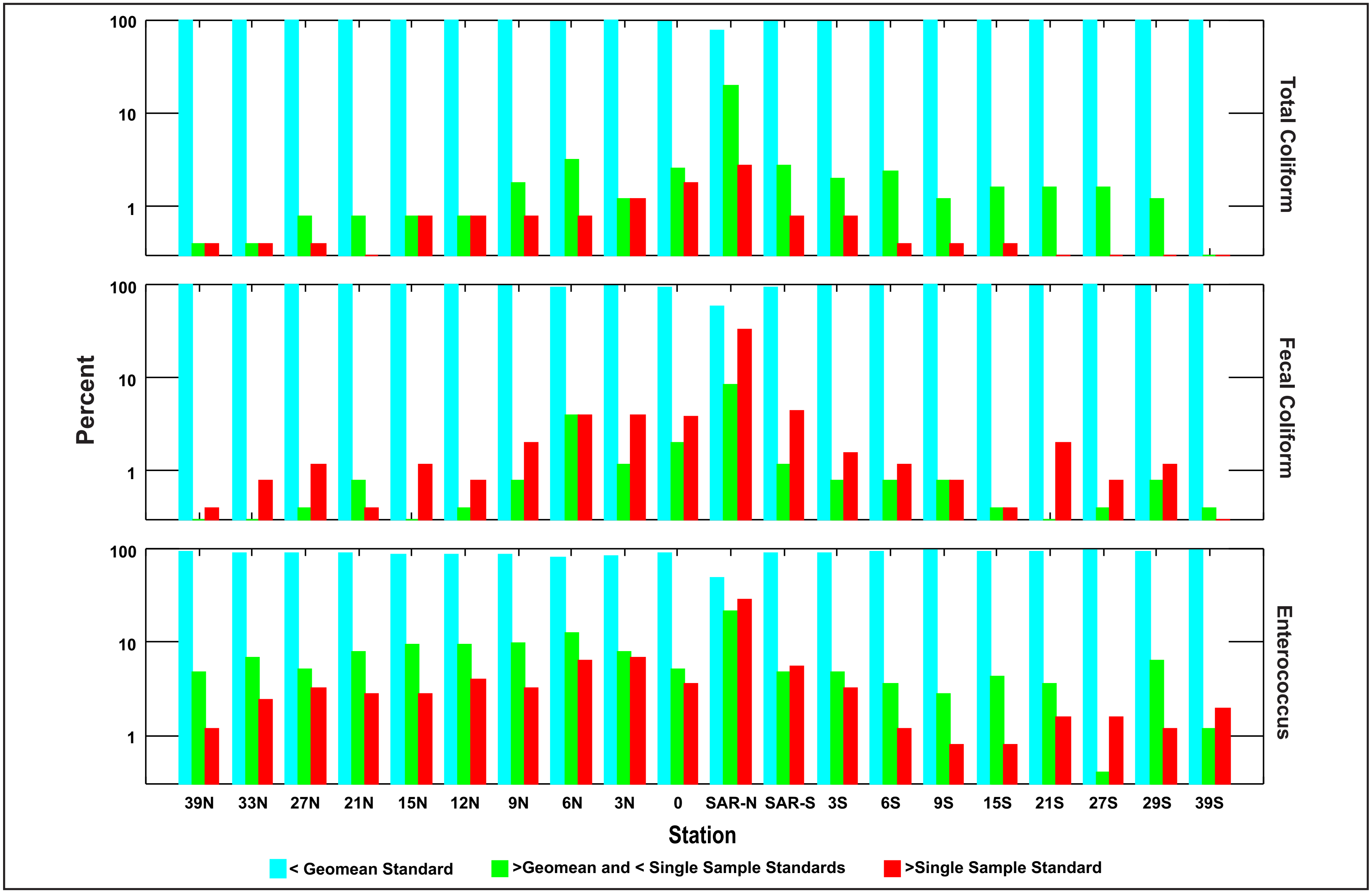


Figure 3-9. **Spatial distribution of total coliform, fecal coliform, and enterococci bacteria at the District's nearshore (surfzone) water quality stations for July 1, 2011 to June 30, 2012.**
Blue bar = values less than the geometric mean standard, green bar = values greater than geometric mean standard and less than the single sample standard, red bar = values greater than the single sample standard.

Orange County Sanitation District, California.

the percent of samples exceeding geomean and single sample standards (Figure 3-9) all peak near the river mouth and then taper off up- and downcoast. Seasonally, summer had the fewest exceedances of the state single sample standard, while fall had the most; this may have been due to the early fall rains in Orange County followed by below average winter rains (see Figure 1-4). Exceedance of the state single sample standard was low at most stations, less than 1% for total coliform, less than 2% for fecal coliform, and less than 4% for enterococci. Exceptions were seen at stations located at and just upcoast of the Santa Ana River where exceedance values ranged up to 3% for total coliform, 33% for fecal coliform, and 29% for enterococci.

Currents and Bottom Temperatures

Current meter and bottom temperature data were not available at all four sites for the entire monitoring year, but there was coverage for all of the water quality surveys at one or more sites (Tables A-2 and A-3). The vast majority (91%) of current speeds for 2011-12 were less than 20 cm/s (or 0.45 mph) with the highest speeds (>40 cm/s) measured less than 2% of the time (Figures 3-10, 3-11, and B-13 to B-18). The predominant flow in the upper 30 meters was oriented alongshore (either 315° or 135°), but directions varied by station. Inshore, at M20, flows were downcoast to 12 m. Below 12 m, there was an even distribution in up- and downcoast flows. At the midshelf station M19, there as a downcoast bias in flow direction in the upper 10 m, with more equi-directional alongshore flows at 15 m. Flows below 15 m, began to show a trend of upcoast transport. At M18, only the surface flows were predominantly downcoast. Flows at intermediate depths showed fairly uniform direction, while flows below 30 m were oriented more in the offshore (270°) direction. M21 flows were consistently alongshore at all depths with a downcoast (~135°) bias down to 50 m. Below 50 m, current direction was evenly divided between up- and downcoast flows. Results were consistent with last year, including a general bias of upcoast flow at typical plume depths (e.g., 20–50 m). While the alongshore flows were consistent with previous current meter results (OCSD 2004, SAIC 2009, SAIC 2011), the predominant upcoast flow regime seen over the last two years differs from previous findings (e.g., SAIC 2009) where the likelihood of up- or downcoast transport at plume depth (waters below 30 m) was nearly equal.

As expected, bottom water temperatures increased from the offshore stations (M18 and M21) to the inshore station, M20 (Figures 3-10 and 3-11, B-13 to B-18). The warmest temperatures occurred in the winter, with minimums seen from early March at all locations. These cold temperatures continued into June at the 40 and 60 m sites, while at the inshore, 20 m site, temperatures began to rise by mid-April.

Temperature and Density

Water temperature varied with depth and season (Table 3-5, Figures 3-12 and B-19). The upper 30 m, had the highest depth-averaged and maximum temperatures, the biggest annual range and, except for winter, values were, typically, twice as variable as those below 30 m. Temperatures below 60 m had the tightest range (1–2.5 °C) and small differences in seasonal means. While winter temperatures were the least variable, there were still significantly higher median values in the upper 30 m. Within season patterns showed that by the September survey, surface temperatures had begun to cool and the mid water started to warm. These conditions lasted into January, with February showing the onset of colder, deeper water mixing into the upper water column. By May and June, warmer surface waters (20 °C) were evident throughout the area.

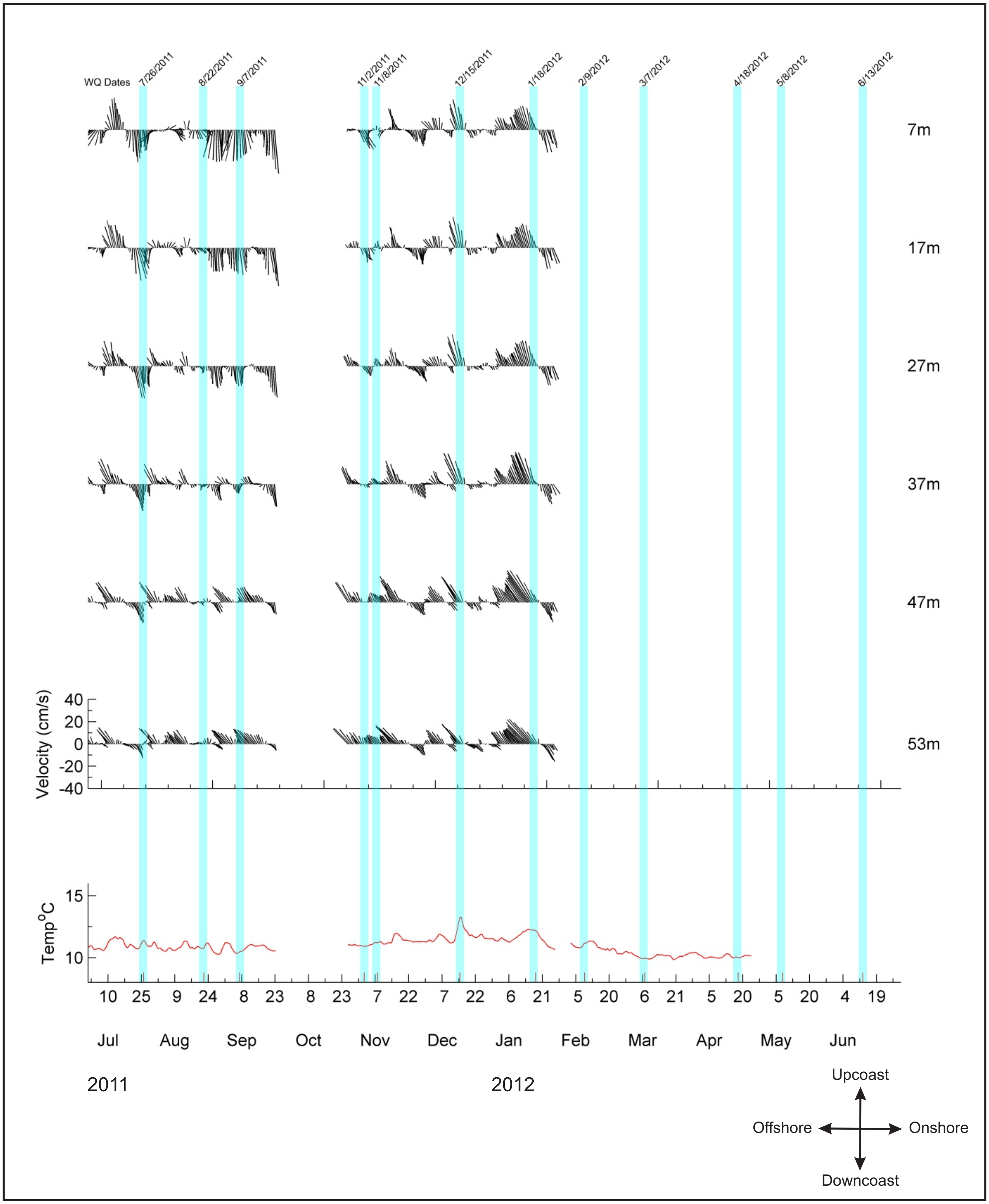


Figure 3-10. **Bottom temperature (°C) and current speed (cm/s) and direction by depth for mooring M-18, July 2011–June 2012. Data processed using a 40 hour low pass filter and rotated 302°.**
Blue lines denote water quality sampling events.

Orange County Sanitation District, California.

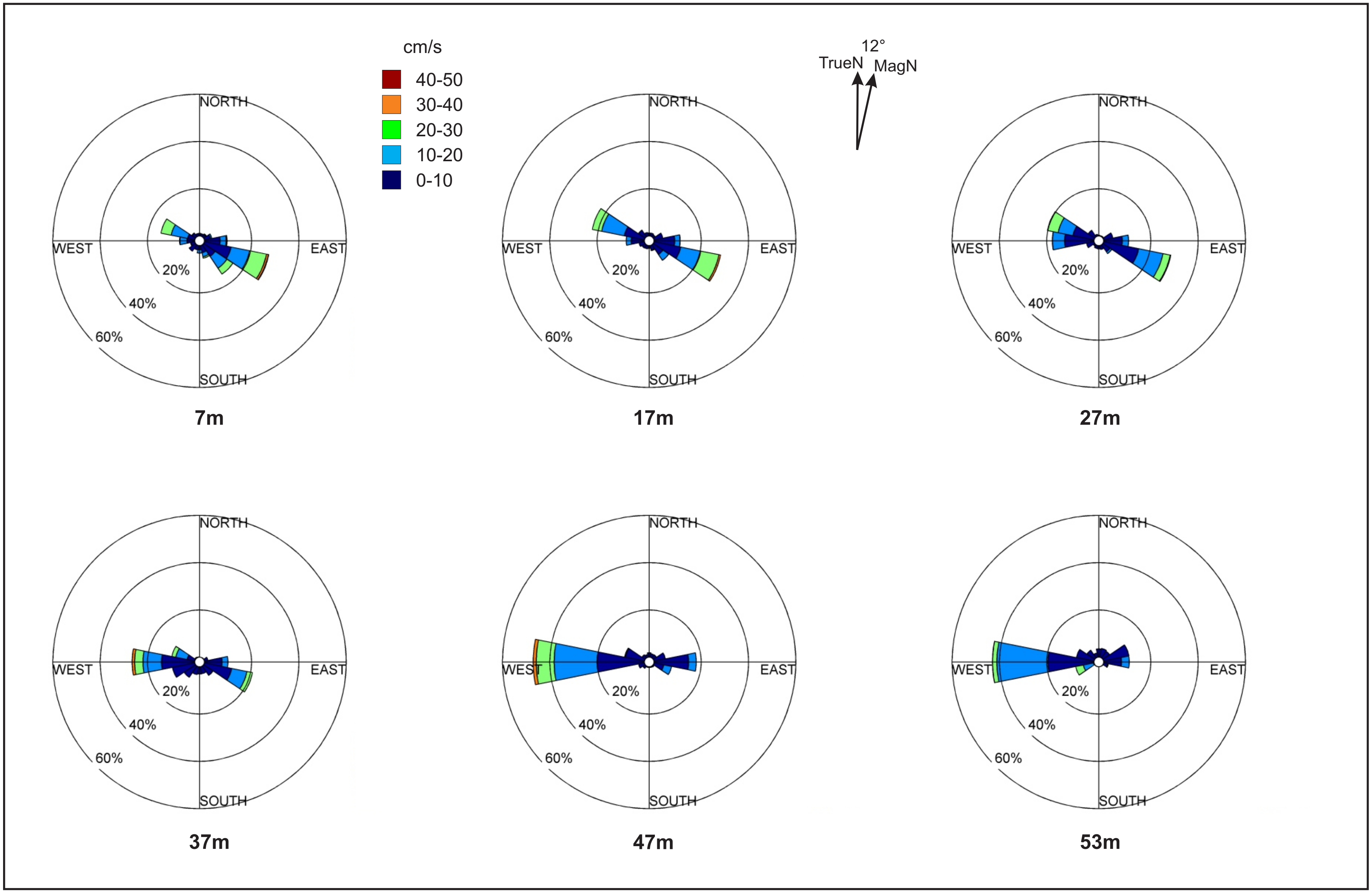


Figure 3-11. **Average current speed (cm/s) and direction by depth for mooring M-18, July 2011–June 2012. Data processed using a 40-hour low pass filter. Direction oriented to true north.**

Orange County Sanitation District, California.

Table 3-5. Summary of quarterly water quality parameters by depth strata and season during 2011-12.

Orange County Sanitation District, California.

Depth (m)	Summer 2011				Fall 2011				Winter 2012				Spring 2012				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Temperature (°C)																				
1-15	14.05	18.19	20.42	1.13	12.28	15.52	17.54	0.62	11.06	14.09	15.52	0.80	11.12	15.97	20.04	2.45	11.06	15.95	20.42	2.06
16-30	11.27	15.00	18.94	1.40	11.17	14.27	16.77	1.13	10.09	13.36	14.76	1.43	10.20	13.12	19.07	1.97	10.09	13.94	19.07	1.69
31-45	10.83	12.54	14.79	0.78	10.77	12.67	15.49	1.33	9.88	12.07	14.61	1.37	10.13	11.21	13.88	0.84	9.88	12.12	15.49	1.25
46-60	10.33	11.38	12.68	0.53	10.70	11.92	14.82	1.28	9.73	11.17	13.37	0.95	9.91	10.50	12.10	0.41	9.73	11.24	14.82	12.54
61-75	10.08	10.75	11.87	0.37	10.26	11.31	14.29	0.91	9.72	10.75	12.43	0.72	9.74	10.20	10.89	0.24	9.72	10.75	14.29	0.73
All	10.08	14.68	20.42	2.99	10.26	13.78	17.54	1.85	9.72	12.81	15.52	1.66	9.74	13.05	20.04	2.86	9.72	13.58	20.42	2.53
delta T (°C)																				
1-15	-0.24	0.16	1.58	0.21	-0.06	0.06	1.23	0.10	-0.26	0.03	0.77	0.08	-0.51	0.19	1.67	0.22	-0.51	0.11	1.67	0.18
16-30	-0.09	0.24	1.66	0.23	-0.11	0.13	1.24	0.17	-0.05	0.08	0.89	0.11	-0.06	0.16	1.48	0.18	-0.11	0.15	1.66	0.19
31-45	-0.09	0.11	1.28	0.13	-0.08	0.08	1.10	0.10	-0.15	0.08	0.57	0.09	-0.12	0.08	0.79	0.10	-0.15	0.08	1.28	0.11
46-60	-0.06	0.06	0.78	0.08	-0.11	0.04	0.44	0.06	-0.13	0.04	0.34	0.05	-0.12	0.02	0.20	0.04	-0.13	0.04	0.78	0.11
61-75	-0.15	0.03	0.44	0.05	-0.10	0.04	1.07	0.09	-0.06	0.02	0.30	0.03	-0.10	0.02	0.16	0.03	-0.15	0.03	1.07	0.06
All	-0.24	0.14	1.66	0.19	-0.11	0.07	1.24	0.12	-0.26	0.05	0.89	0.09	-0.51	0.12	1.67	0.18	-0.51	0.10	1.67	0.16
Density (kg/m^3)																				
1-15	23.34	24.04	24.87	0.27	23.97	24.59	25.21	0.12	24.51	24.92	25.65	0.20	23.69	24.63	25.86	0.55	23.34	24.54	25.86	0.45
16-30	23.87	24.71	25.50	0.28	24.39	24.83	25.50	0.22	24.77	25.09	25.99	0.34	23.96	25.28	25.99	0.45	23.87	24.98	25.99	0.40
31-45	24.75	25.18	25.63	0.17	24.58	25.15	25.73	0.28	24.80	25.37	26.13	0.38	25.06	25.70	26.05	0.24	24.58	25.35	26.13	0.35
46-60	25.13	25.43	25.76	0.14	24.75	25.35	25.83	0.31	25.01	25.61	26.22	0.34	25.42	25.90	26.16	0.18	24.75	25.58	26.22	25.18
61-75	25.33	25.62	25.87	0.11	24.84	25.55	25.90	0.27	25.22	25.76	26.26	0.31	25.67	26.01	26.23	0.15	24.84	25.74	26.26	0.28
All	23.34	24.77	25.87	0.62	23.97	24.95	25.90	0.40	24.51	25.22	26.26	0.43	23.69	25.30	26.23	0.66	23.34	25.06	26.26	0.58
Salinity (psu)																				
1-15	33.17	33.46	33.68	0.05	33.06	33.35	33.48	0.05	33.05	33.38	33.57	0.07	33.13	33.58	33.74	0.06	33.05	33.44	33.74	0.11
16-30	33.19	33.37	33.52	0.06	33.24	33.33	33.50	0.04	33.27	33.42	33.79	0.10	33.47	33.62	33.86	0.09	33.19	33.43	33.86	0.13
31-45	33.16	33.32	33.49	0.06	33.16	33.33	33.60	0.07	33.21	33.45	33.92	0.17	33.36	33.67	33.91	0.13	33.16	33.44	33.92	0.18
46-60	33.17	33.36	33.55	0.07	33.20	33.40	33.74	0.11	33.25	33.55	34.01	0.22	33.44	33.76	34.02	0.14	33.17	33.52	34.02	33.32
61-75	33.30	33.45	33.64	0.07	33.28	33.51	33.81	0.15	33.34	33.64	34.09	0.23	33.50	33.83	34.04	0.15	33.28	33.61	34.09	0.22
All	33.16	33.40	33.68	0.08	33.06	33.36	33.81	0.09	33.05	33.45	34.09	0.17	33.13	33.66	34.04	0.13	33.05	33.47	34.09	0.17

Table 3-5 continues.

Table 3-5 continued.

Depth (m)	Summer 2011				Fall 2011				Winter 2012				Spring 2012				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Dissolved Oxygen (mg/L)																				
1-15	5.69	7.69	9.50	0.50	5.89	7.64	9.76	0.42	4.26	7.74	9.98	0.79	4.25	7.83	10.68	0.94	4.25	7.73	10.68	0.70
16-30	5.33	7.85	9.73	0.67	5.46	7.53	10.05	0.58	3.17	6.64	8.84	1.50	3.12	6.27	8.86	1.64	3.12	7.07	10.05	1.36
31-45	4.88	6.77	8.88	0.72	4.64	6.80	9.23	0.84	2.84	5.28	8.06	1.33	2.55	4.42	8.01	1.44	2.55	5.82	9.23	1.52
46-60	4.46	6.08	7.36	0.59	4.14	5.95	7.60	0.89	2.66	4.53	6.39	1.04	1.74	3.56	6.54	1.08	1.74	5.02	7.60	6.77
61-75	4.22	5.59	6.72	0.53	3.30	5.15	7.19	0.85	2.47	4.10	5.61	0.94	2.24	3.30	5.62	0.94	2.24	4.52	7.19	1.23
All	4.22	7.14	9.73	1.01	3.30	6.99	10.05	1.08	2.47	6.21	9.98	1.77	1.74	5.77	10.68	2.16	1.74	6.53	10.68	1.68
Dissolved Oxygen Saturation (%)																				
1-15	75.12	99.60	118.69	5.76	71.68	93.98	118.23	5.05	47.92	92.54	119.17	10.24	47.88	97.48	130.29	13.40	47.88	95.91	130.29	9.68
16-30	60.04	95.59	119.19	9.38	61.59	90.36	121.91	7.58	34.92	78.67	104.38	19.37	34.74	74.28	108.51	21.99	34.74	84.76	121.91	18.01
31-45	54.54	78.48	105.56	9.35	51.98	79.13	108.21	11.40	31.18	60.94	96.53	16.80	28.17	50.12	94.68	17.24	28.17	67.14	108.21	18.71
46-60	49.60	68.72	84.64	7.19	46.31	68.18	92.11	11.81	29.12	51.20	75.19	12.52	19.25	39.61	74.43	12.37	19.25	56.86	92.11	78.48
61-75	46.51	62.37	75.60	6.28	36.86	58.26	85.98	10.56	27.13	45.88	64.74	11.03	24.99	36.44	62.26	10.49	24.99	50.58	85.98	14.19
All	46.51	86.89	119.19	15.86	36.86	83.32	121.91	14.99	27.13	73.00	119.17	22.68	19.25	68.89	130.29	28.79	19.25	78.02	130.29	22.58
pH (pH units)																				
1-15	8.13	8.30	8.44	0.08	8.02	8.24	8.36	0.06	7.82	8.12	8.35	0.06	7.71	8.08	8.30	0.10	7.71	8.18	8.44	0.12
16-30	8.01	8.24	8.46	0.08	7.96	8.17	8.29	0.08	7.73	8.03	8.25	0.12	7.60	7.93	8.19	0.17	7.60	8.09	8.46	0.17
31-45	7.91	8.12	8.42	0.07	7.91	8.09	8.26	0.08	7.70	7.90	8.13	0.12	7.56	7.74	8.09	0.14	7.56	7.96	8.42	0.19
46-60	7.88	8.05	8.23	0.07	7.87	8.03	8.17	0.08	7.68	7.82	8.03	0.09	7.52	7.65	7.93	0.09	7.52	7.89	8.23	8.12
61-75	7.85	8.00	8.21	0.08	7.81	7.97	8.14	0.07	7.67	7.78	7.95	0.07	7.53	7.62	7.79	0.07	7.53	7.84	8.21	0.17
All	7.85	8.19	8.46	0.13	7.81	8.14	8.36	0.12	7.67	7.98	8.35	0.16	7.52	7.88	8.30	0.22	7.52	8.05	8.46	0.20
Chlorophyll-*a* (µg/L)																				
1-15	0.66	2.71	39.15	2.88	0.28	6.26	28.41	5.61	0.31	2.50	27.11	3.18	0.22	3.06	33.18	4.64	0.22	3.63	39.15	4.50
16-30	1.12	6.72	38.18	4.43	0.59	4.98	21.04	3.44	0.23	2.01	22.82	2.37	0.36	2.34	14.80	1.96	0.23	4.02	38.18	3.75
31-45	1.29	5.36	14.75	2.50	0.57	2.27	9.05	1.31	0.13	1.14	14.46	1.60	0.19	1.19	6.82	0.72	0.13	2.49	14.75	2.39
46-60	0.69	2.50	8.35	1.24	0.48	1.21	3.53	0.51	0.09	0.54	14.82	1.34	0.09	0.51	1.81	0.36	0.09	1.19	14.82	5.36
61-75	0.44	1.30	3.78	0.61	0.22	0.70	1.64	0.22	0.08	0.22	0.56	0.11	0.06	0.23	0.88	0.15	0.06	0.61	3.78	0.55
All	0.44	4.06	39.15	3.62	0.22	3.98	28.41	4.27	0.08	1.63	27.11	2.48	0.06	1.90	33.18	3.03	0.06	2.90	39.15	3.60

Table 3-5 continues.

Table 3-5 continued.

Depth (m)	Summer 2011				Fall 2011				Winter 2012				Spring 2012				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Light Transmission (%)																				
1-15	66.24	85.01	88.02	2.71	64.25	82.57	88.56	4.80	47.25	81.14	87.76	6.56	50.17	81.38	86.93	6.51	47.25	82.53	88.56	5.59
16-30	57.58	84.06	88.11	3.86	71.74	84.59	88.56	2.86	52.44	83.28	87.78	5.62	65.45	83.02	87.93	3.78	52.44	83.74	88.56	4.19
31-45	64.03	84.68	88.20	3.60	70.74	85.98	89.01	2.58	51.96	84.84	88.85	5.06	63.07	84.16	88.22	3.67	51.96	84.91	89.01	3.88
46-60	54.13	85.05	88.99	5.62	56.63	85.76	89.15	4.64	55.63	86.02	89.27	5.34	68.44	85.29	89.29	3.46	54.13	85.52	89.29	84.68
61-75	79.43	86.54	89.31	2.13	80.27	87.18	89.26	1.65	82.04	87.85	89.37	1.15	80.26	86.53	89.50	2.25	79.43	87.02	89.50	1.93
All	54.13	84.87	89.31	3.70	56.63	84.60	89.26	4.05	47.25	83.70	89.37	5.96	50.17	83.37	89.50	4.99	47.25	84.13	89.50	4.79
Beam C (1/m)																				
1-15	0.51	0.65	1.65	0.14	0.49	0.77	1.77	0.24	0.52	0.85	2.94	0.36	0.56	0.84	2.78	0.36	0.49	0.78	2.94	0.30
16-30	0.51	0.70	2.21	0.20	0.49	0.67	1.33	0.14	0.52	0.74	2.58	0.30	0.51	0.75	1.70	0.19	0.49	0.72	2.58	0.22
31-45	0.50	0.67	1.78	0.18	0.47	0.61	1.39	0.12	0.47	0.67	2.62	0.27	0.50	0.69	1.85	0.18	0.47	0.66	2.62	0.20
46-60	0.47	0.66	2.46	0.30	0.46	0.62	2.27	0.24	0.45	0.61	2.35	0.28	0.45	0.64	1.52	0.17	0.45	0.63	2.46	0.67
61-75	0.45	0.58	0.92	0.10	0.46	0.55	0.88	0.08	0.45	0.52	0.79	0.05	0.44	0.58	0.88	0.11	0.44	0.56	0.92	0.09
All	0.45	0.66	2.46	0.19	0.46	0.67	2.27	0.20	0.45	0.72	2.94	0.32	0.44	0.74	2.78	0.26	0.44	0.70	2.94	0.25
CDOM (µg/L)																				
1-15	0.27	0.56	1.56	0.17	0.71	1.61	4.92	0.74	0.95	1.79	4.05	0.62	0.97	1.76	3.78	0.53	0.27	1.43	4.92	0.75
16-30	0.46	0.93	1.79	0.22	0.78	1.70	4.39	0.68	1.02	2.12	4.91	0.74	1.23	2.41	4.46	0.52	0.46	1.79	4.91	0.80
31-45	0.66	1.13	2.66	0.38	0.90	1.60	3.68	0.49	1.19	2.68	5.39	0.72	1.78	2.86	6.34	0.78	0.66	2.07	6.34	0.95
46-60	0.67	1.06	2.69	0.36	0.93	1.53	3.00	0.34	1.91	2.46	4.82	0.38	1.78	2.71	5.26	0.58	0.67	1.94	5.26	1.13
61-75	0.74	0.89	1.23	0.08	1.04	1.42	1.94	0.19	2.02	2.33	2.96	0.18	1.93	2.48	3.47	0.23	0.74	1.79	3.47	0.68
All	0.27	0.86	2.69	0.34	0.71	1.60	4.92	0.61	0.95	2.18	5.39	0.70	0.97	2.32	6.34	0.70	0.27	1.74	6.34	0.84
PAR (µE/(cm^2·sec))																				
1-15	0.81	12.31	95.20	10.32	0.16	12.93	100.00	14.44	0.05	13.22	100.00	14.03	0.17	20.06	100.00	17.81	0.05	14.65	100.00	14.74
16-30	0.02	2.87	10.30	1.74	0.08	1.86	8.90	1.56	0.00	2.25	9.40	1.80	0.08	3.45	14.29	2.85	0.00	2.61	14.29	2.14
31-45	0.00	0.58	2.20	0.34	0.04	0.44	2.40	0.38	0.00	0.52	2.26	0.41	0.05	0.70	2.90	0.56	0.00	0.56	2.90	0.44
46-60	0.00	0.20	1.05	0.17	0.04	0.18	1.25	0.17	0.00	0.18	0.87	0.15	0.04	0.25	0.86	0.18	0.00	0.21	1.25	0.58
61-75	0.00	0.12	0.72	0.13	0.04	0.12	1.01	0.15	0.00	0.10	0.46	0.08	0.04	0.17	0.52	0.13	0.00	0.13	1.01	0.13
All	0.00	4.89	95.20	7.92	0.04	4.81	100.00	10.03	0.00	5.02	100.00	9.90	0.04	7.56	100.00	13.45	0.00	5.58	100.00	10.59

Table 3-5 continues.

Table 3-5 continued.

Depth (m)	Summer 2011				Fall 2011				Winter 2012				Spring 2012				Annual			
	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev	Min	Mean	Max	Std Dev
Ammonia (mg/L)																				
1-15	<0.02	<0.02	0.07	0.00	<0.02	0.02	0.23	0.01	<0.02	0.02	0.11	0.01	<0.02	0.02	0.08	0.00	<0.02	0.02	0.23	0.01
16-30	<0.02	0.02	0.08	0.01	<0.02	0.02	0.06	0.01	<0.02	0.02	0.15	0.02	<0.02	0.03	0.12	0.02	<0.02	0.02	0.15	0.02
31-45	<0.02	0.04	0.20	0.04	<0.02	0.03	0.15	0.03	<0.02	0.03	0.13	0.02	<0.02	0.03	0.11	0.02	<0.02	0.03	0.20	0.03
46-60	<0.02	0.03	0.15	0.03	<0.02	0.02	0.11	0.02	<0.02	0.02	0.07	0.01	<0.02	0.03	0.07	0.02	<0.02	0.02	0.15	0.04
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	<0.02	0.02	0.20	0.02	<0.02	0.02	0.23	0.02	<0.02	0.02	0.15	0.01	<0.02	0.02	0.12	0.01	<0.02	0.02	0.23	0.02
Total Coliform Bacteria (MPN/100 mL)																				
1-15	<10	8	52	3	<10	9	41	4	<10	10	145	12	<10	8	74	5	<10	9	145	7
16-30	<10	8	20	2	<10	12	63	11	<10	53	1722	244	<10	18	169	31	<10	23	1722	123
31-45	<10	13	63	14	<10	23	142	31	<10	76	520	145	<10	47	246	73	<10	39	520	84
46-60	<10	10	31	6	<10	15	52	13	<10	24	195	44	<10	41	404	93	<10	22	404	13
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	<10	8	63	5	<10	11	142	12	<10	24	1722	111	<10	15	404	37	<10	15	1722	59
Fecal Coliform Bacteria (MPN/100 mL)																				
1-15	<10	8	11	0	<10	8	11	0	<10	8	34	3	<10	<10	<10	0	<10	8	34	1
16-30	<10	<10	<10	0	<10	8	34	4	<10	17	285	40	<10	9	34	6	<10	10	285	21
31-45	<10	8	11	1	<10	11	45	8	<10	18	107	26	<10	12	45	11	<10	12	107	15
46-60	<10	8	11	1	<10	8	11	1	<10	11	57	11	<10	13	45	12	<10	10	57	8
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	<10	8	11	0	<10	8	45	3	<10	11	285	19	<10	9	45	5	<10	9	285	10
Enterococcus Bacteria (MPN/100 mL)																				
1-15	<10	8	75	6	<10	8	75	5	<10	8	63	5	<10	8	30	2	<10	8	75	5
16-30	<10	8	10	0	<10	8	20	2	<10	10	41	7	<10	9	52	6	<10	9	52	5
31-45	<10	8	10	1	<10	8	10	1	<10	13	31	8	<10	8	20	3	<10	9	31	5
46-60	<10	8	10	1	<10	11	75	15	<10	9	20	4	<10	9	30	6	<10	9	75	8
61-75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All	<10	8	75	5	<10	8	75	6	<10	9	63	6	<10	8	52	4	<10	8	75	5

NS = No sample

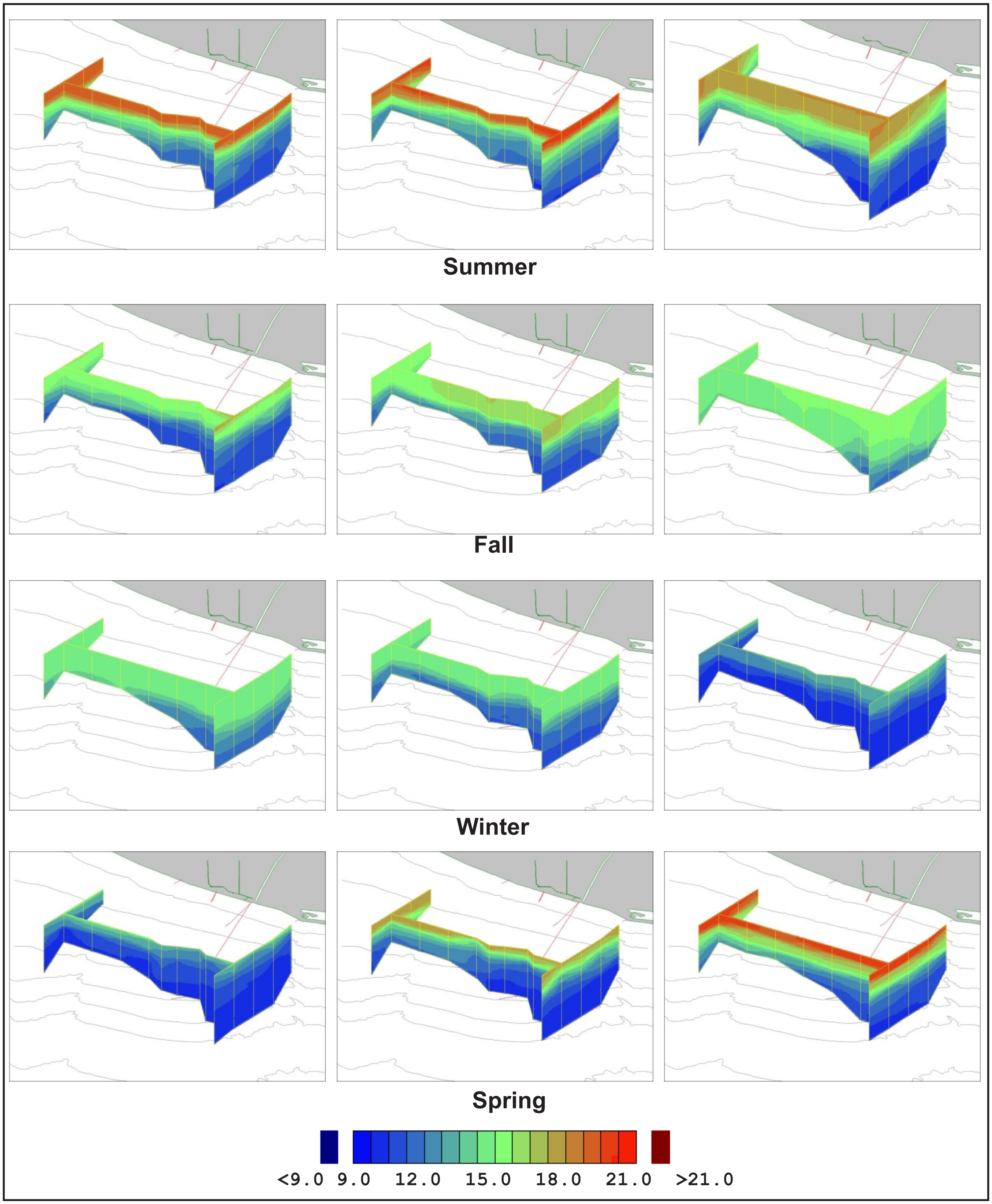


Figure 3-12. **Seasonal patterns of temperature (°C) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

Changes in water temperature with depth (delta-T) showed that the water column was stratified into late fall (December 15 survey) when surface waters cooled and the thermocline weakened (Table 3-5, Figures 3-13, and B-20). With the incursion of colder bottom water, stratification began to set up in February, but it did not become fully established until May.

Since daily monitoring results are "snap-shots" of conditions in the study area, it was not possible to evaluate the intra-season variability. The Regional Ocean Modeling System (ROMS), maintained by the Southern California Ocean Observing System (SCCOOS), provides hourly output of 3-dimensional water temperatures. SCCOOS (2013a) provided a one-year model run of temperature for a location near the District's outfall to look at finer scale changes during the program year (Figure B-21). Model and monitoring data showed generally good agreement throughout the year. Strong summer stratification transitioned into weaker stratification by December, with both a general cooling of surface water and warming downward into the water column. The District did not sample in October, but model output would indicate that strong stratification was present. Winter and spring comparisons showed a continued weakening of thermal stratification from October to February, with weak or no stratification in March and April. Both sets of "data" showed the onset of stratification by May with a return to strongly stratified conditions by June. While the program data seemed to catch the major phases seen during the year, the ROMS output highlights the complexity of temperature changes throughout the year, such as the rapid warming or cooling of the water column that can occur in a matter of days.

Density was highly correlated with temperature (r=-0.98) with comparable seasonal and depth related patterns (Table 3-5; Figures 3-14 and B-22). Overall, for temperature and density, the ranges, mean values, and spatial and temporal patterns for 2011-12 were typical of long-term District observations (OCSD 1996b; 2004; SAIC 2009).

Plume Related Changes

The predicted plume impact would be a slight increase in water temperature after mixing. This direct effect seems offset by the entrainment of colder, denser water as the buoyant plume rises in the water column (Figures 3-12 and 3-14, August 22, 2011). For temperature, entrainment did not significantly affect the outfall area. Profiles for outfall Station 2205 all fell within measured values from stations not impacted by the discharge (Figures 3-14 and B-22) and the calculated level of change (Table 3-1) was within natural variability.

<u>Salinity</u>

For 2011-12, salinity values had a narrow range with minimum and maximum values of 33.05 and 34.09 psu, respectively (Table 3-5). A prominent feature from July to February was the presence of a layer of lower salinity water between 15 and 45 m (Figures 3-15 and B-23). This water is a combination of discharged effluent and regional, subarctic water described above. Higher salinity water was seen at depth from March to May, due either to upwelling or the current driven impingement of deeper oceanic waters. June again had the subsurface low salinity feature. Other features seen through the year included reductions in surface salinity during the late winter and early spring most likely due to runoff from land.

As was the case for temperature, the general patterns and ranges for salinity were consistent with long-term monitoring (e.g., summarized in OCSD 1996b, 2004).

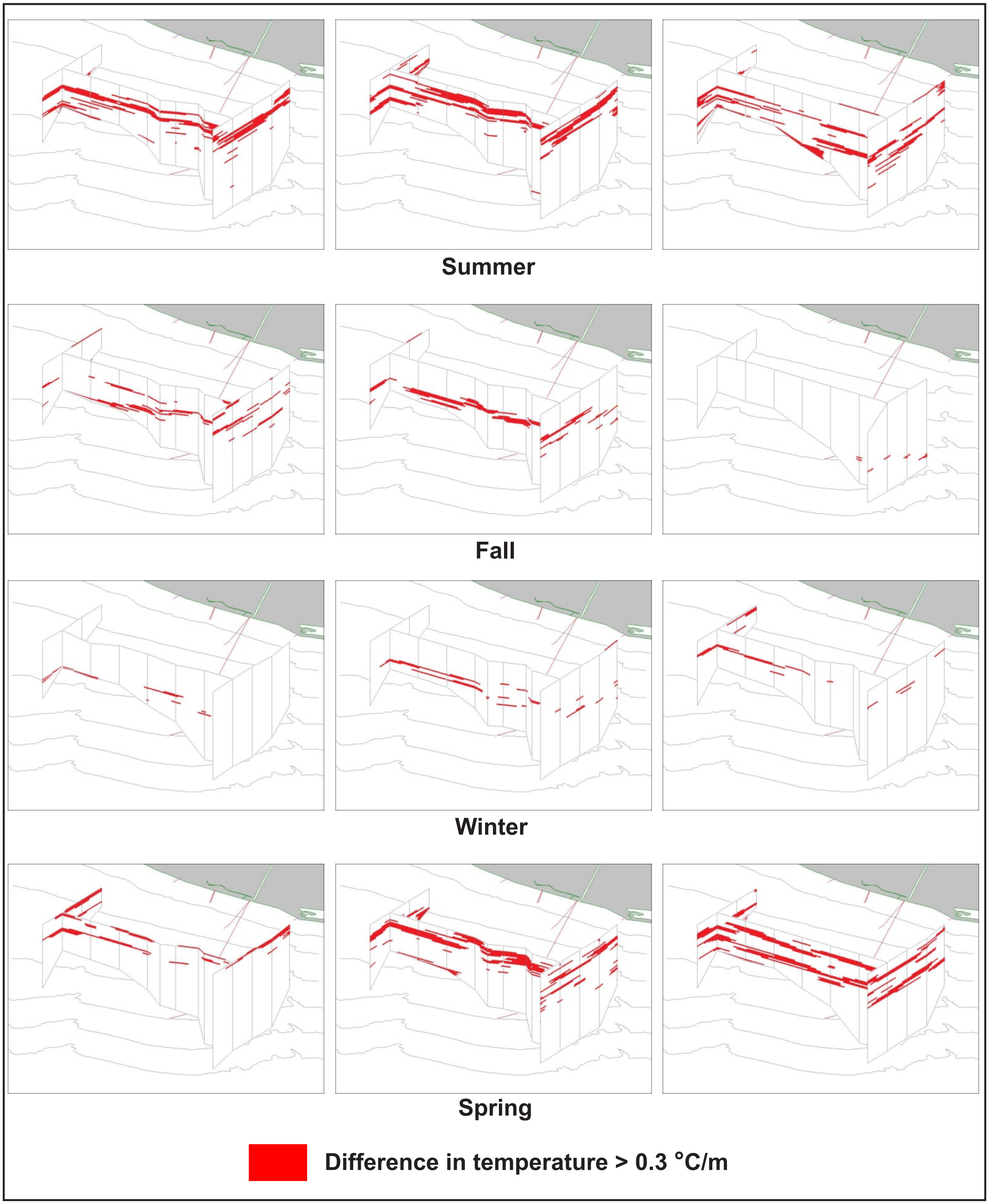


Figure 3-13. **Seasonal patterns of thermocline depth for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

The thermocline is defined as change in temperature >0.3 °C/m.

Orange County Sanitation District, California.

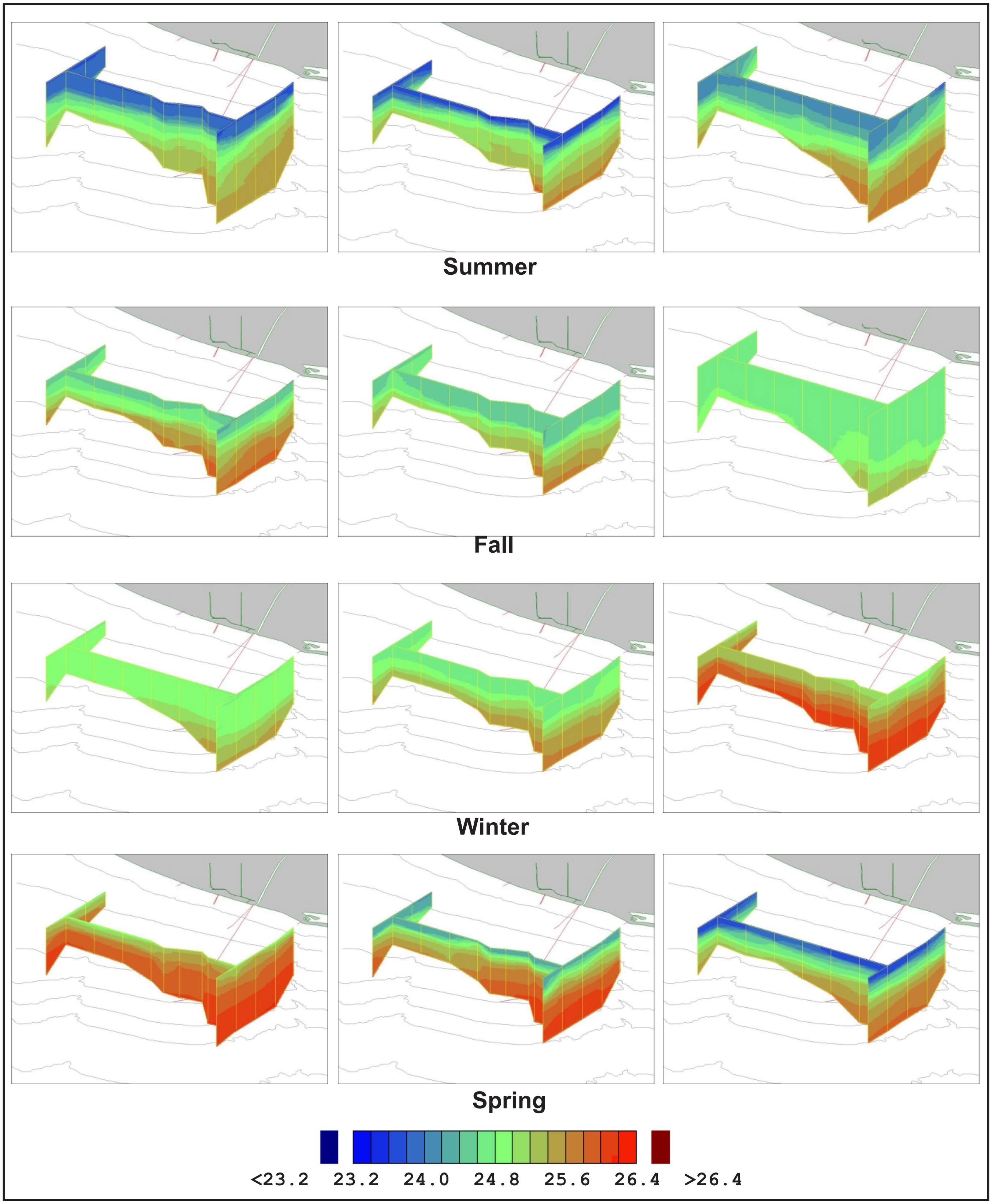


Figure 3-14. **Seasonal patterns of density (kg/m^3) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

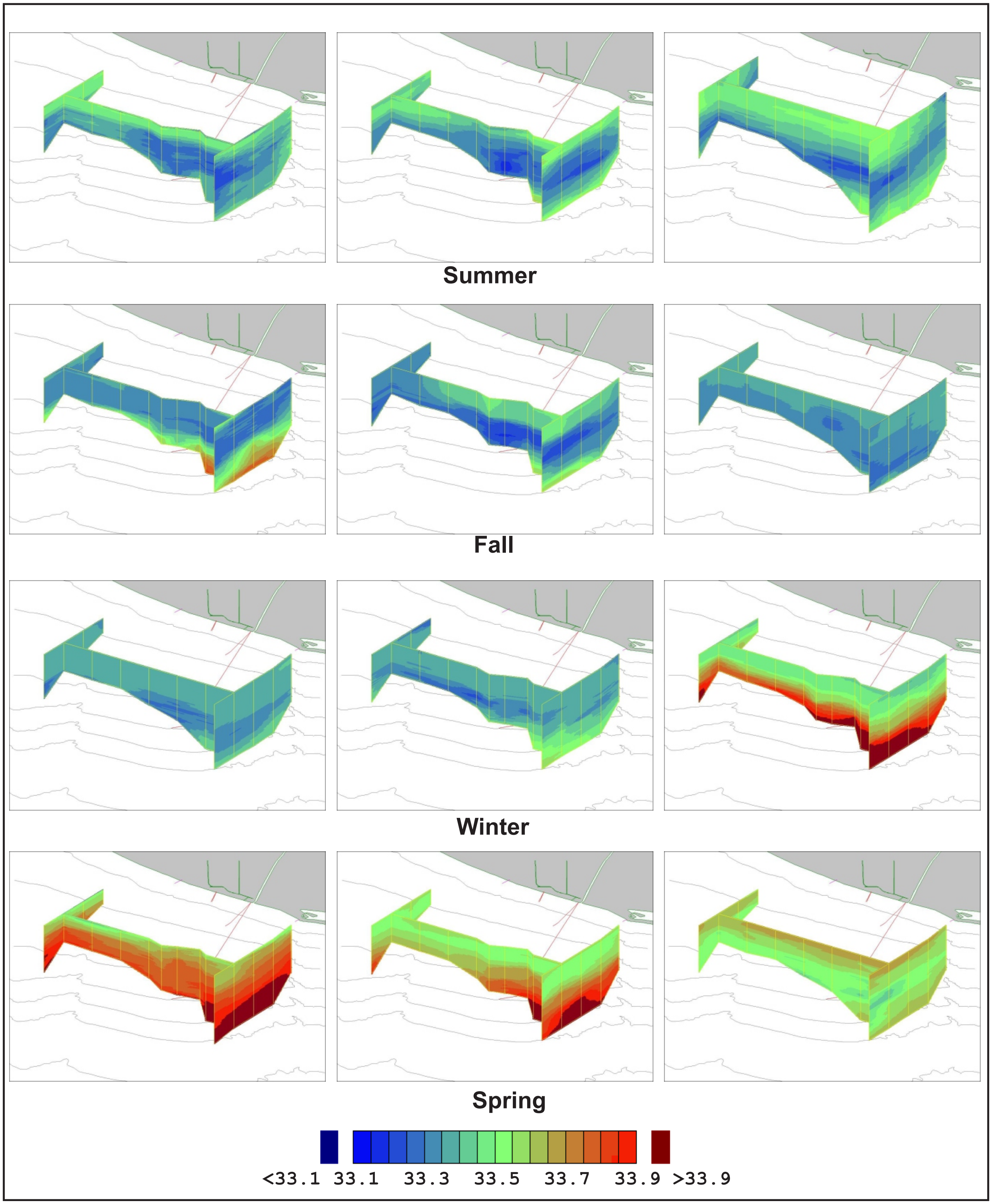


Figure 3-15. **Seasonal patterns of salinity (psu) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

Plume Related Changes
The plume is essentially a freshwater source discharged into saline waters, so a primary plume signature is the reduction in salinity after initial dilution. Discharge-related decreases in salinity of about 0.03 psu, apparent each quarter below the pycnocline or at mid-depth, were less than the predicted decrease (Table 3-1) and were not significantly different from non-outfall stations (Figure B-23). The subsequent transport of the lower salinity plume water was consistent with measured currents (see Figure 3-10). For example, the area of low subsurface salinity in July illustrates the impact of a transition of currents from down- to upcoast.

<u>Dissolved Oxygen, and pH</u>
Water temperature, salinity, depth, and phytoplankton all influence oxygen concentrations. Nearly 90% of the DO values were above 4 mg/L with only a few (4 out of 21,633) measurements indicative of hypoxic conditions (<2 mg/L). While the average and median seasonal DO values generally decreased with depth for all seasons (Table 3-5, Figures 3-16, B-24, and B-25) a feature often seen is a subsurface oxygen maximum around 25 m. Spring had the largest range (1.74–10.7 mg/L) and had the lowest average and minimum DO values overall and for each depth bin. Summer and fall DO values were comparable, while the lower winter values at depths below 30 meters reflected the onset of upwelling. The 2011-12 DO patterns and values were consistent with long-term monitoring results (summarized in OCSD 1996b, 2004).

Dissolved oxygen and pH were well correlated (r=0.82) both spatially and seasonally so patterns between the two were similar (Table 3-5, Figures 3-17 and B-26). Mean values decreased from the surface to the bottom with highest average pH during summer. No values in 2011-12 were below 7.5, a level at which slight reductions in hatching and survival of juvenile copepods and euphausids have been measured (Peterson et al. 2010). These general patterns for pH were consistent with past monitoring years (e.g., OCSD 1996a, b, 2004–2011).

Plume Related Changes
The major DO and pH spatial patterns were not plume related, but did coincide with deeper water impinging onto the shelf or with elevated chlorophyll-*a*. Localized decreases in DO and pH were mostly due to the rising plume causing entrainment of deeper water with lower DO and pH (Figures 3-16 and 3-17 August 22). Values at outfall Station 2205 fell within the range of values and were not statistically different from non-outfall stations (B-24 to B-26). Overall there were few instances of >10% depression of DO values relative to background conditions and compliance with criterion C.4.a was above 98% (Chapter 2), while the pH criterion (C.4.b) was met >99% this year.

<u>Water Clarity and Color</u>

Percent Transmissivity
Overall, water clarity for the year was high (mean values >80%) at all depths (Table 3-5; Figures 3-18, B-27, and B-28). The most notable feature was the reduced light transmittance seen in the Newport Canyon during all surveys. Additional lower values were see in surface to mid-water depths in November and April throughout the study area associated with lower surface salinities (see discussion above) and elevated levels of

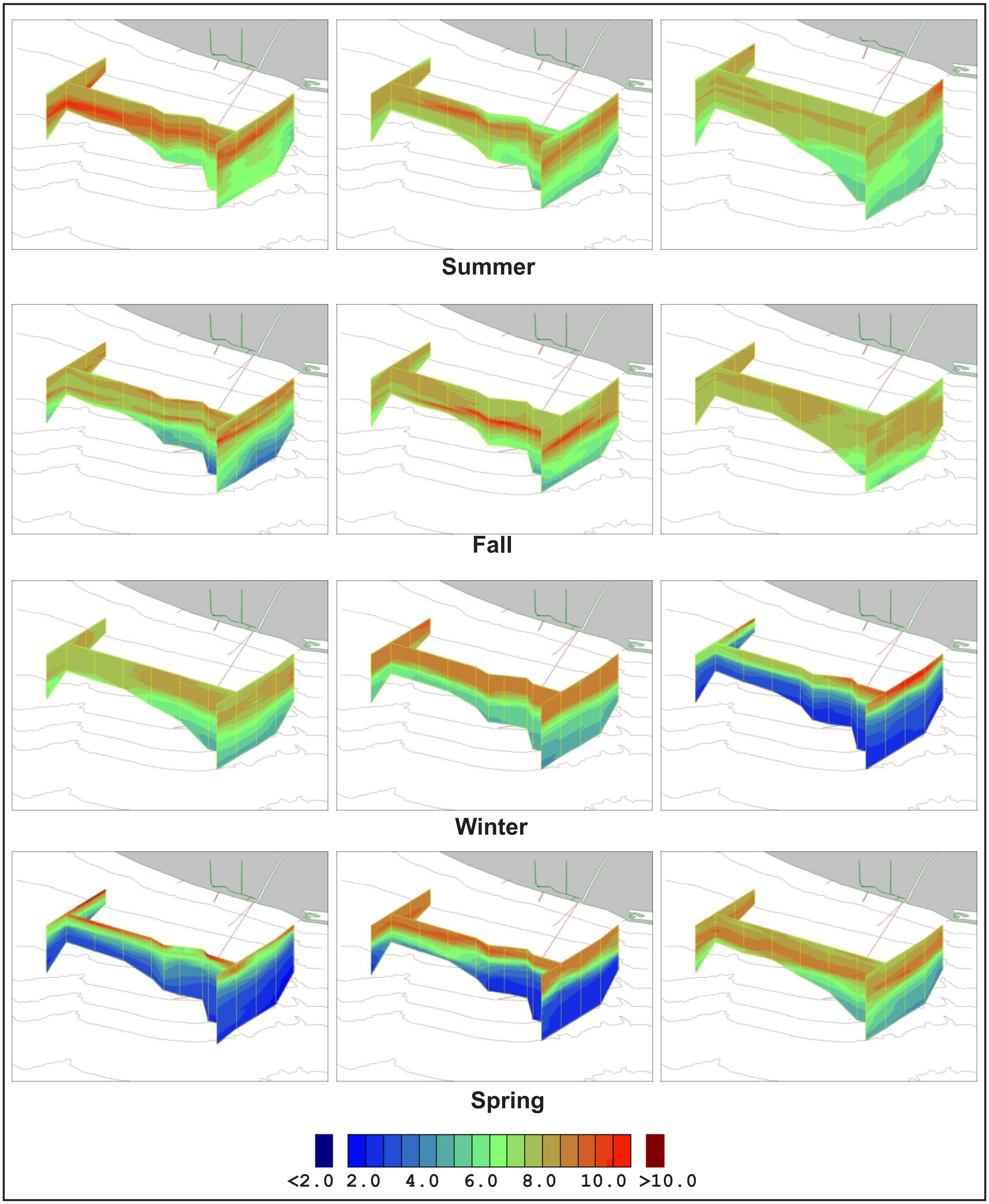


Figure 3-16. Seasonal patterns of dissolved oxygen (mg/L) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).

Orange County Sanitation District, California.

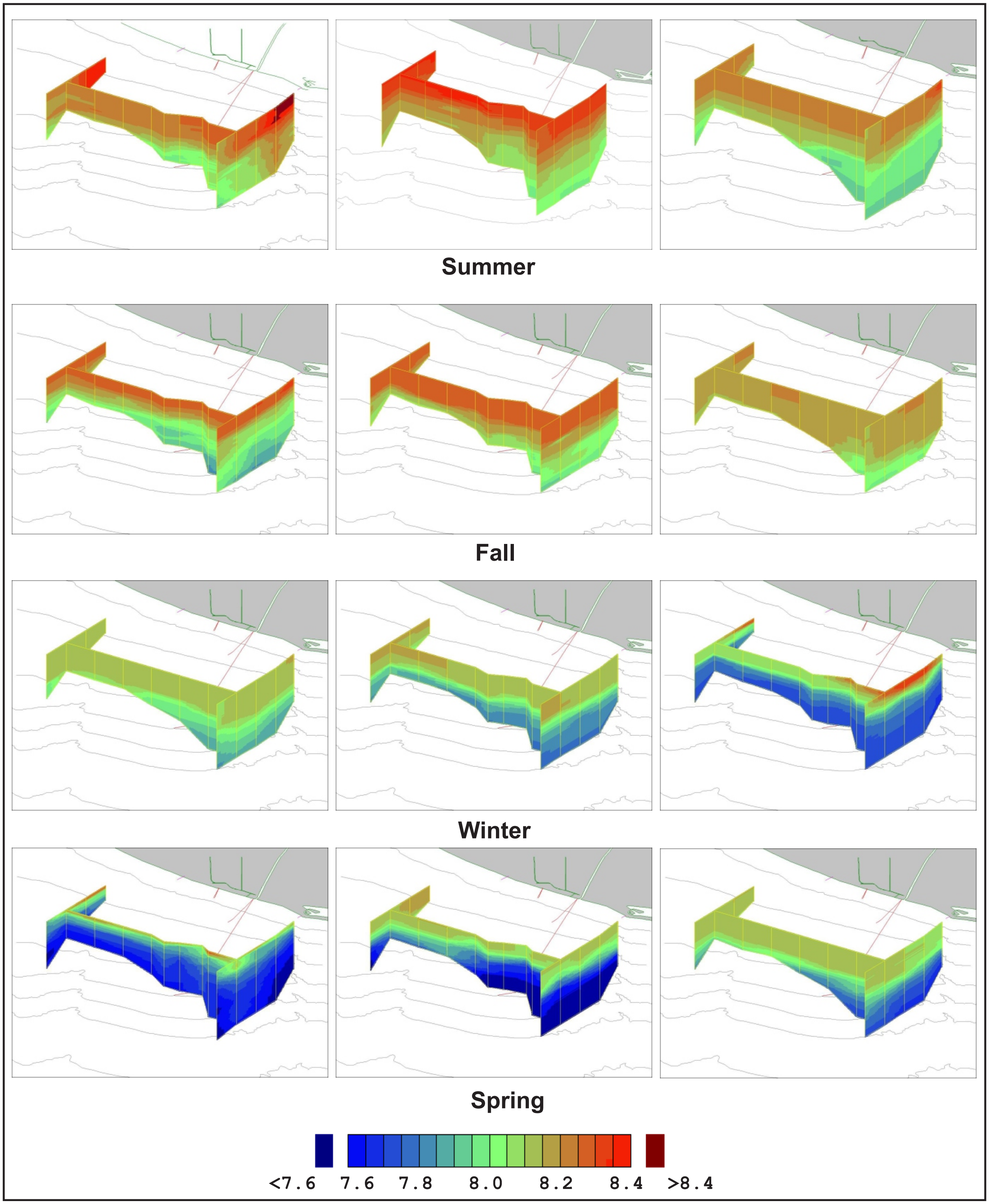


Figure 3-17. **Seasonal patterns of pH for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

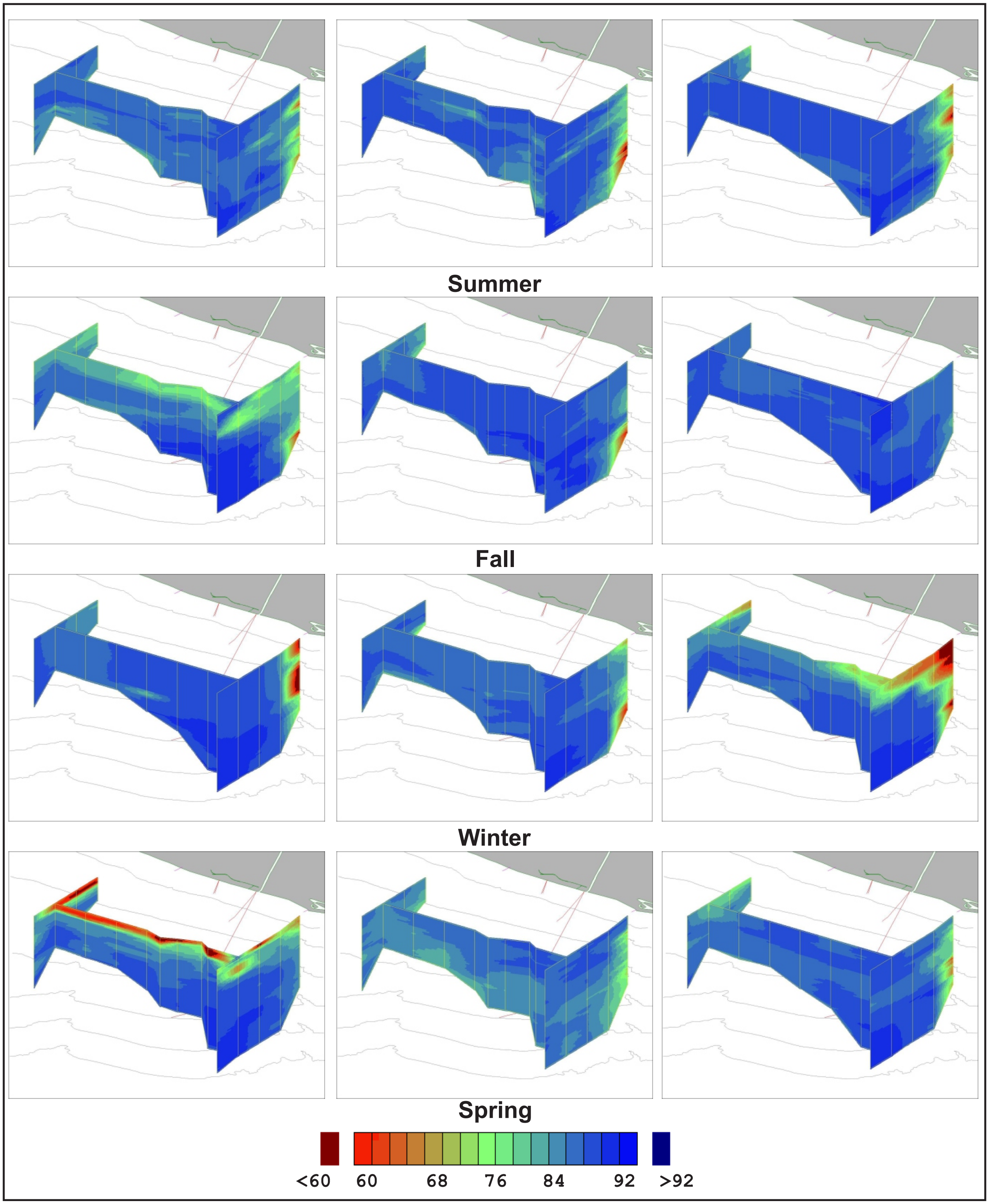


Figure 3-18. **Seasonal patterns of light transmission (%) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

chlorophyll-*a* (see discussion below). Generally, transmissivity data was comparable to regional values, but was slightly lower overall and at all depths.

Colored Dissolved Organic Matter (CDOM)

Despite the other sources of CDOM, such as rivers, zooplankton, and bacteria (Kowalczuk et al. 2003, Steinberg et al. 2004), its use has proven to be a reliable plume tracer in southern California (Jones et al. 2011, Rogowski et al. 2011). Plume-related CDOM effects matched well with salinity (Figures 3-19 and B-29). Changes were mostly limited to depths below 15 m, with the highest values in the summer at depths between 15–45 m (Table 3-5). Elevated CDOM values in the upper 15 m of water were co-located with elevated chlorophyll-*a* or associated with the Newport Canyon and land-based sources, (Figure 3-20).

Secchi and Water Color

Spatial and temporal patterns in Secchi depth and water color data were generally consistent with the transmissivity results. The lowest water clarity (shallowest Secchi depth and highest Forel/Ule values) occurred at the nearshore stations and in the Newport Canyon (Station C2) with progressively clearer water with increasing distance offshore during most surveys (Figures 3-21 and 3-22). Waters were clearest in the fall and winter and the most turbid in the spring. In April, increased Forel values corresponded to elevated chlorophyll levels measured at the Newport Pier (SCCOOS 2013b).

Photosynthetically Active Radiation (PAR)

Light levels rapidly decreased within the upper 10 m of the water column (Figures 3-23 and B-30). The range of depths for the 10% light level was between 1–15 m (Table 3-5). The 1% light level (euphotic zone depth) was as deep as 60 m in all seasons, though, on average, it was limited to the upper 30 m of the water column. Spring had the clearest surface and depth averaged conditions.

Both the 10% and 1% PAR light levels were significantly correlated to Secchi depth (r=0.15 and 0.68, respectively). However, there was a closer affinity in the spatial patterns between the 1% light levels and Secchi depth than to the 10% light levels (Figure 3-24). Intuitively, this makes sense since both the 1% PAR and Secchi depth measure a more comparable light extinction endpoint.

Chlorophyll-a

Measurements of chlorophyll-a fluorescence, used as a surrogate to collecting discrete samples for phytoplankton, are an indicator of phytoplankton abundance and biomass in coastal waters. While chlorophyll-*a* does not distinguish between the source of chlorophyll (terrestrial versus marine) or plankton species, high concentrations typically indicate high phytoplankton biomass and reflect a potential response to nutrient loads. For 2011-12, summer had the highest maximum and depth-averaged mean values, while winter had the lowest (Table 3-5). Elevated chlorophyll-*a* was measured subsurface (31–60 m) in the summer and from the surface down to 45 m in the fall. Subsurface maxima were muted in the winter and spring (Figures 3-23, 3-25, and B-31). Chlorophyll blooms were evident from July through November with the highest percentage in October (Table 3-6). From December to February no or a small percentage of the samples reached bloom levels. March and April showed an increased number of bloom occurrences, with subsequent

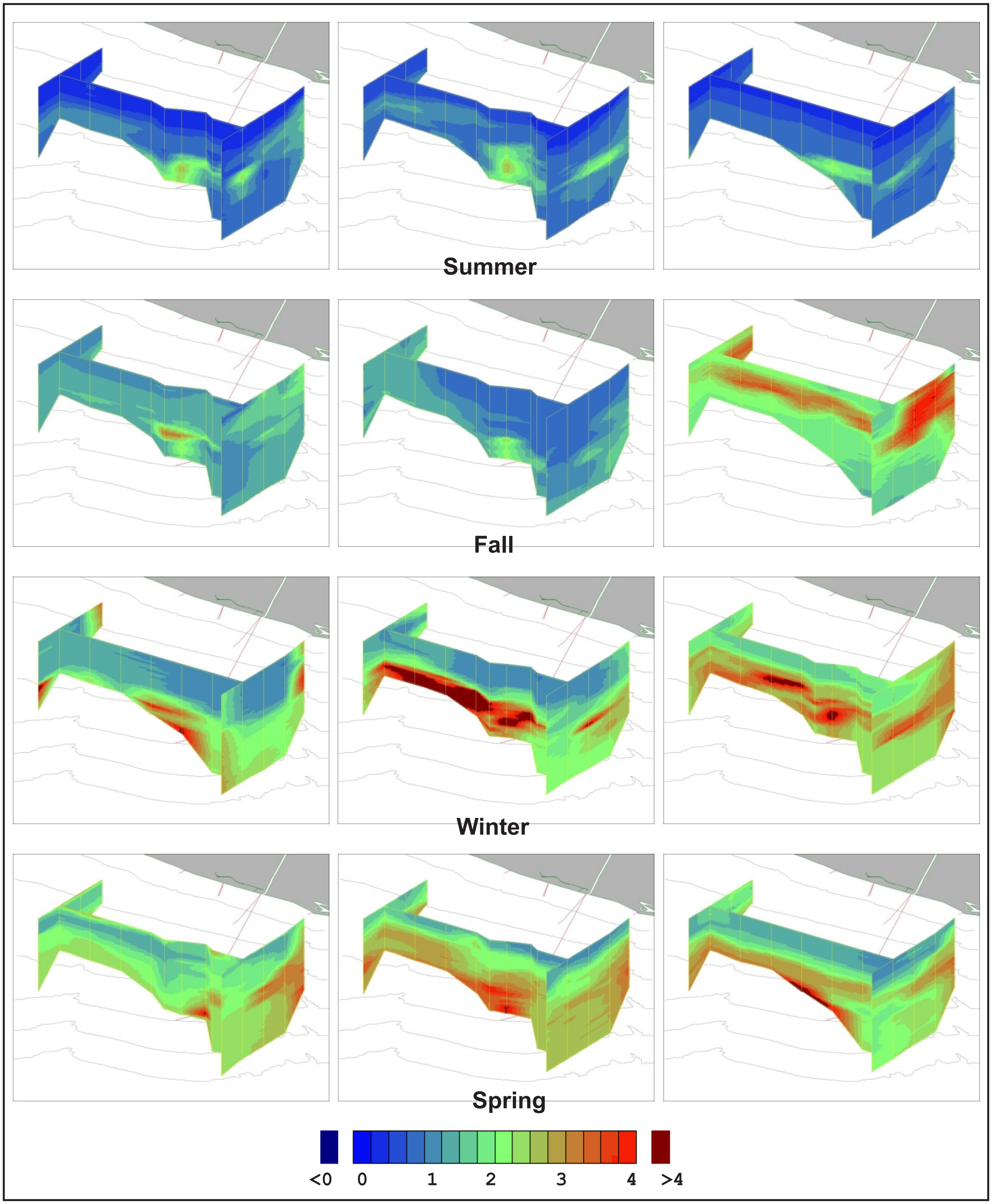


Figure 3-19. **Seasonal patterns of color dissolved organic matter (CDOM, µg/L) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

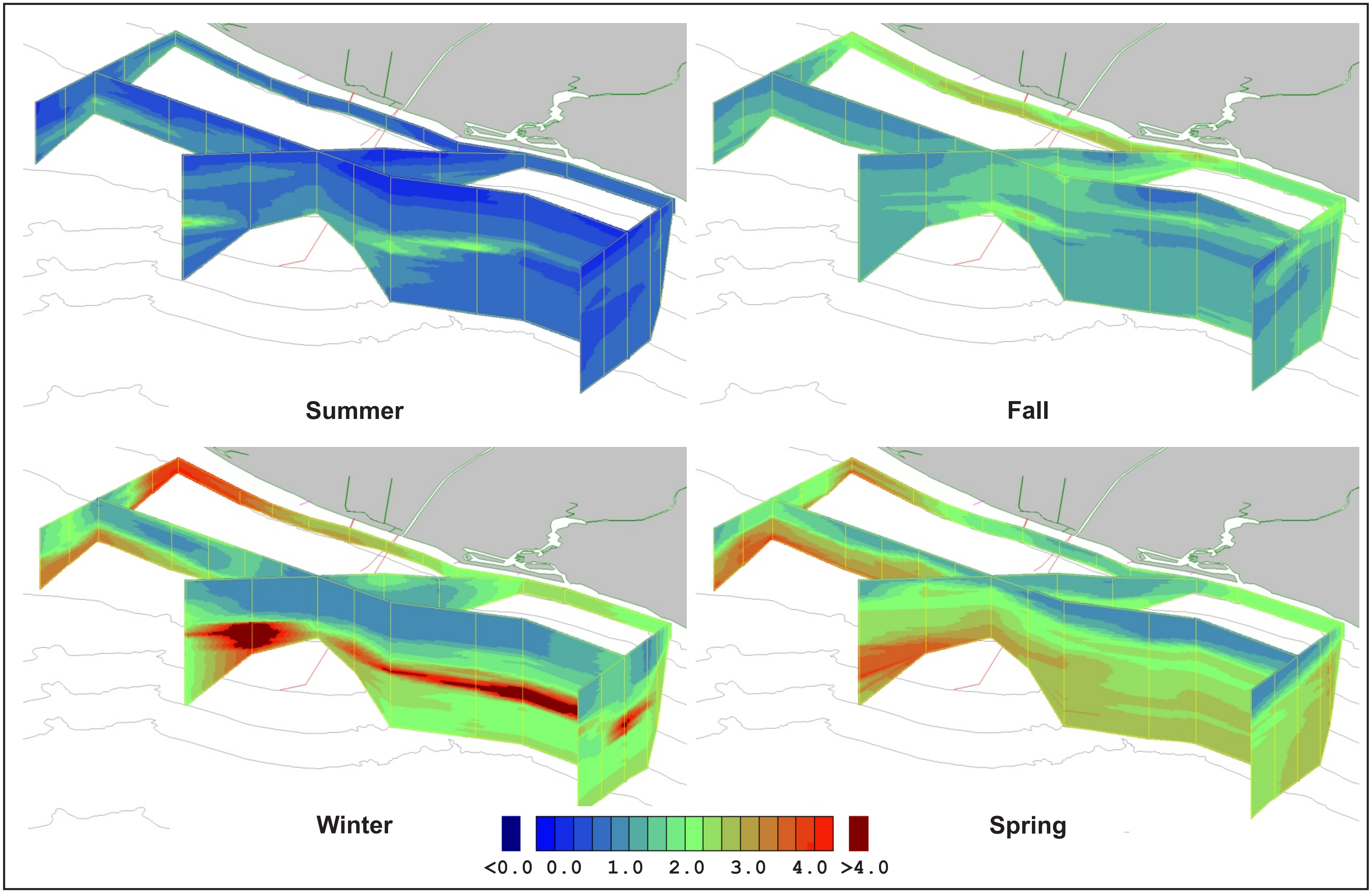


Figure 3-20. Seasonal patterns of color dissolved organic matter (CDOM, µg/L) at OCSD regional stations for summer (August 2011), fall (November 2011), winter (February 2012), and spring (May 2012).

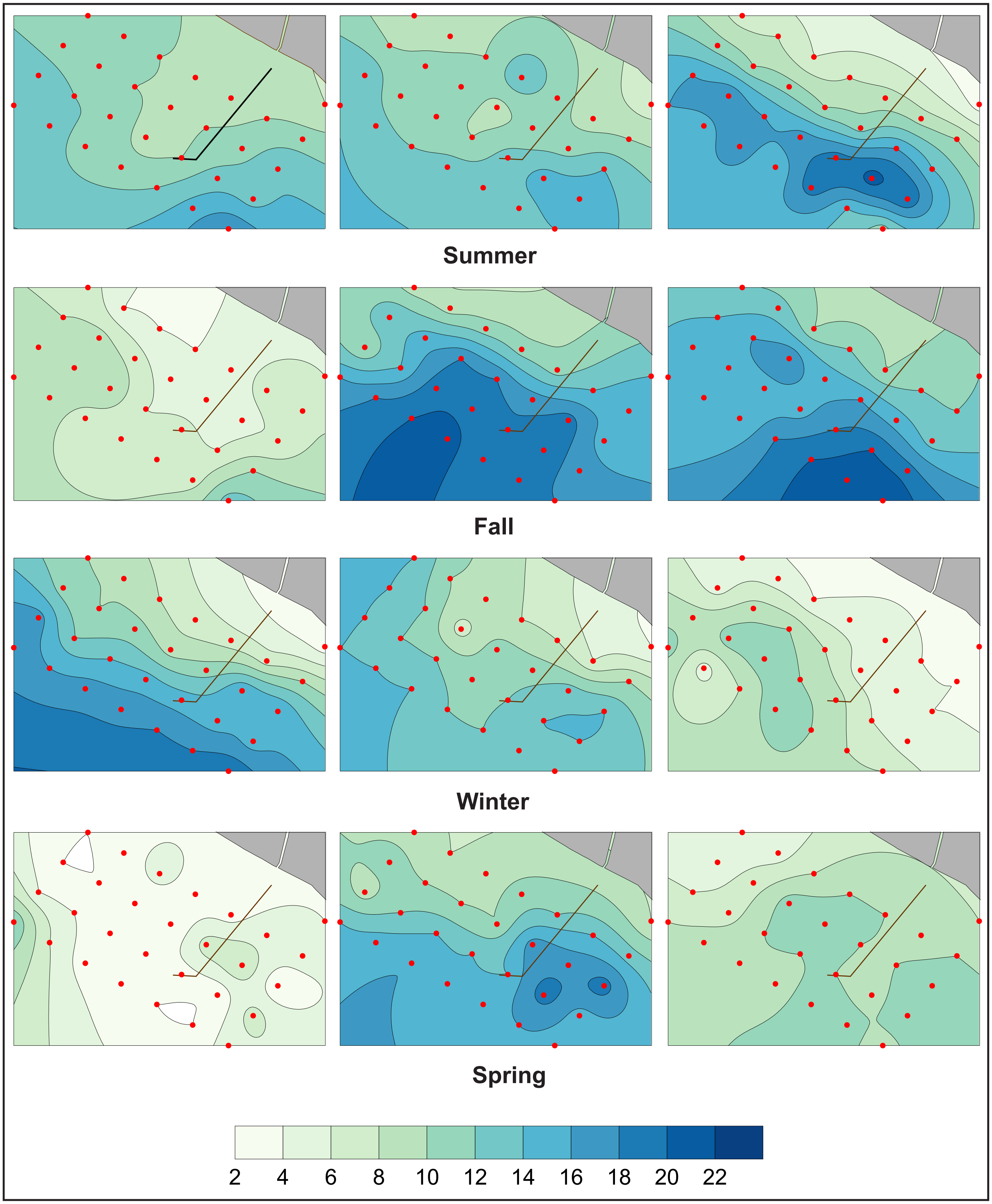


Figure 3-21. **Seasonal patterns of secchi depth (m) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Higher values indicate clearer water.
Orange County Sanitation District, California.

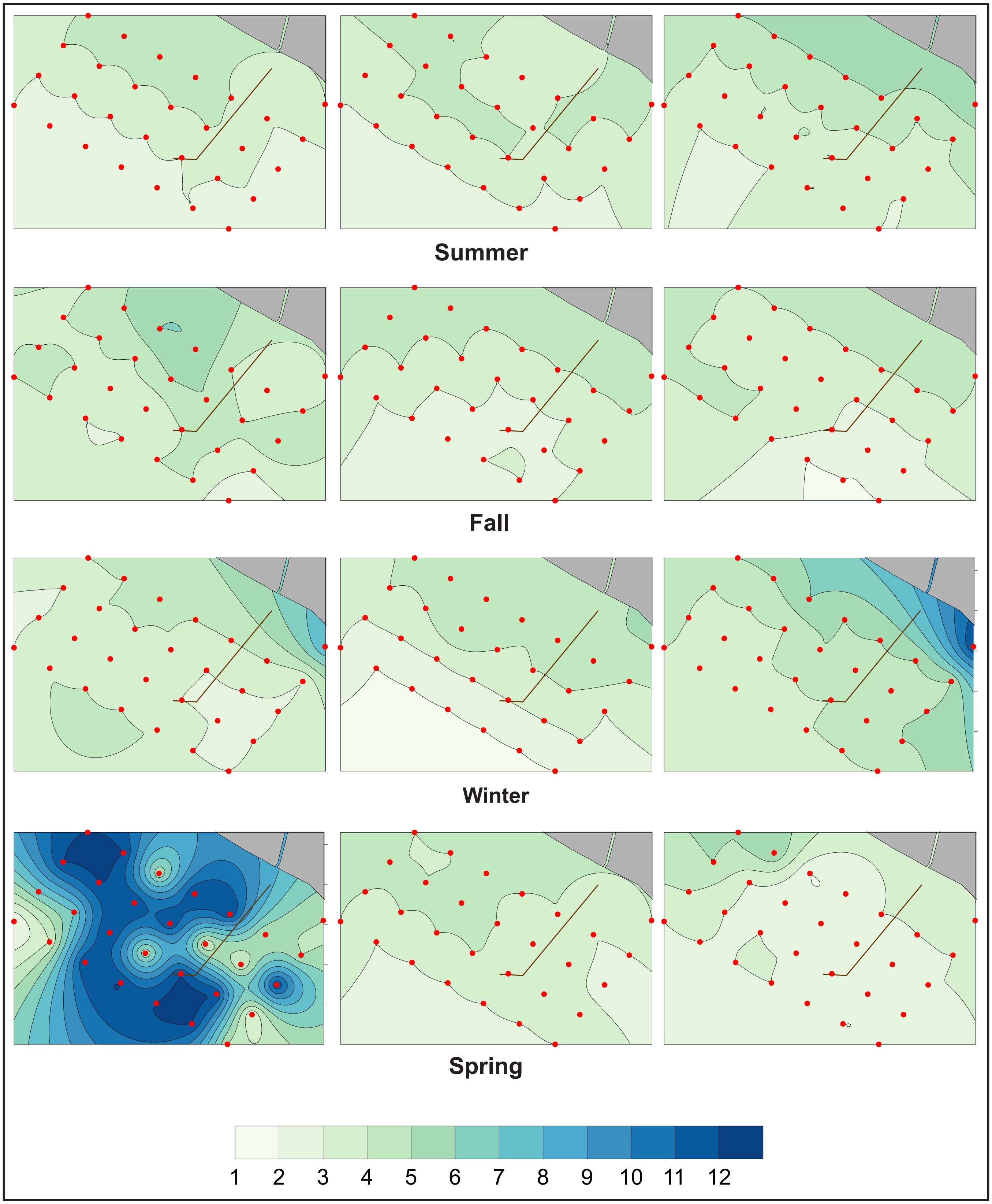


Figure 3-22. Seasonal patterns of water color (Forel/Ule) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).

Lower values indicate clearer water.
Orange County Sanitation District, California.

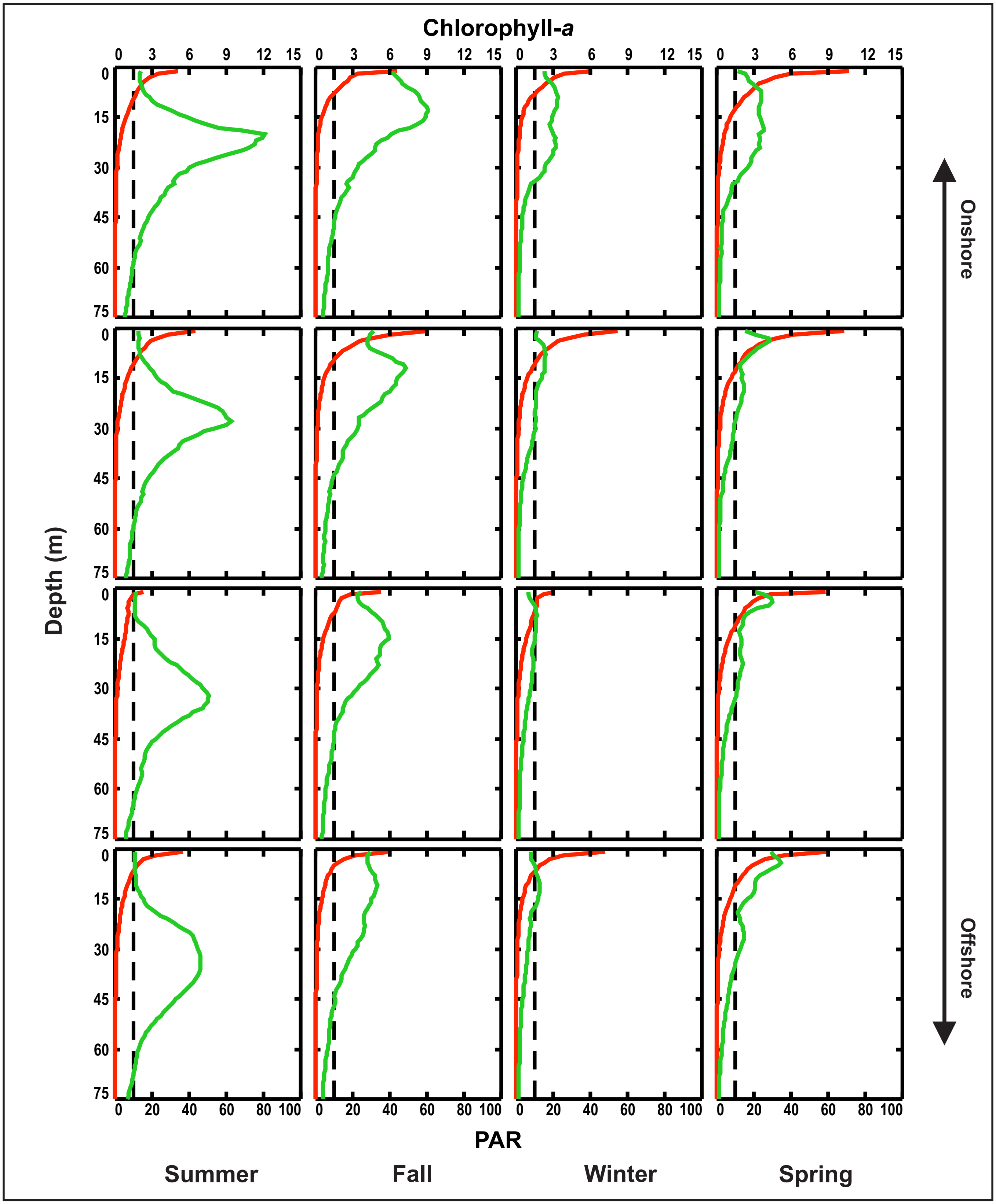


Figure 3-23. **Quarterly average chlorophyll-*a* fluorescence (µg/L; green line) and photosynthetically active radiation (PAR; µE/(cm^2·sec); red line) with depth for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Black vertical dashed line represents the 10% light penetration level.

Orange County Sanitation District, California.

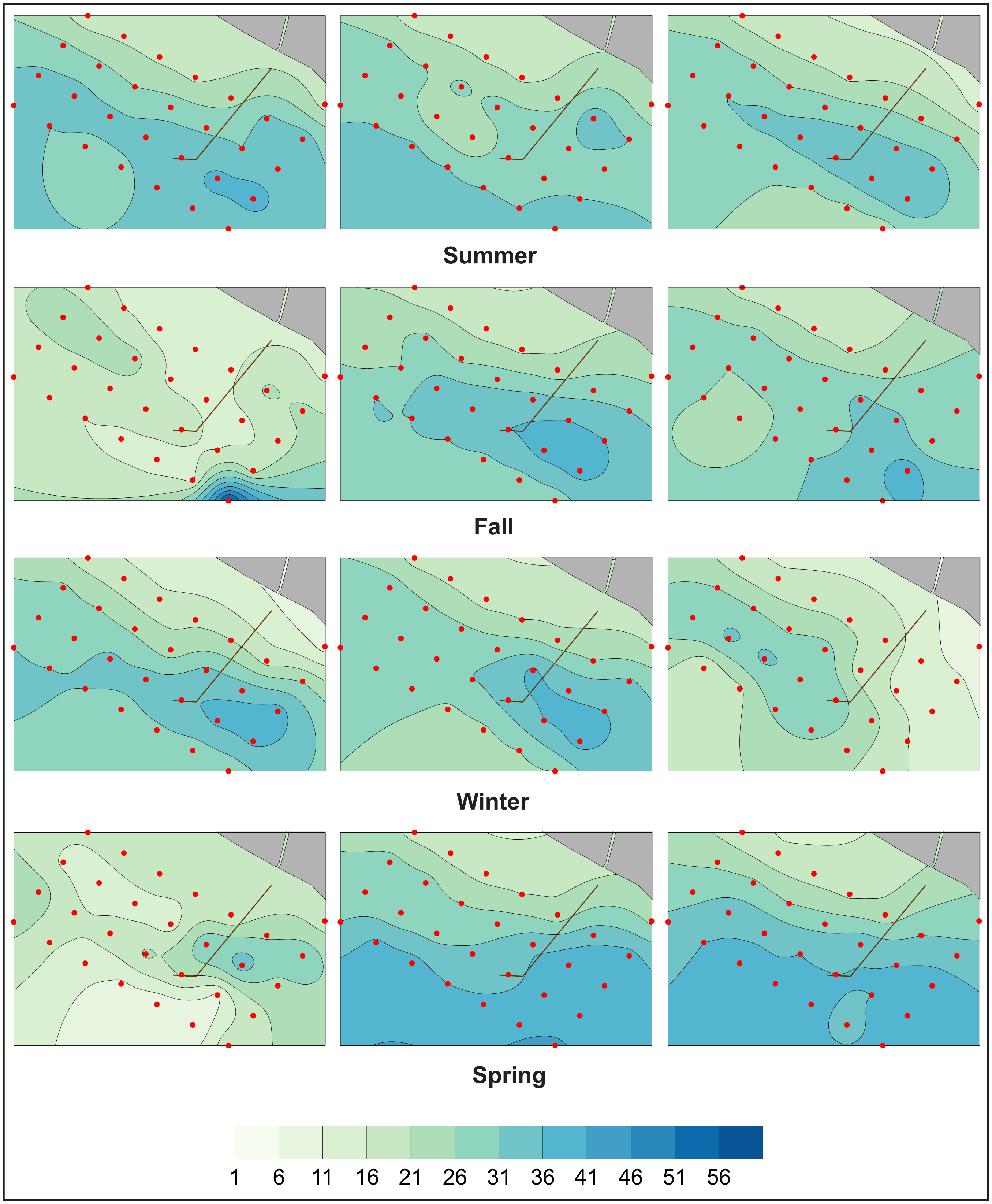


Figure 3-24. **Seasonal patterns of 1% PAR depth (m) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

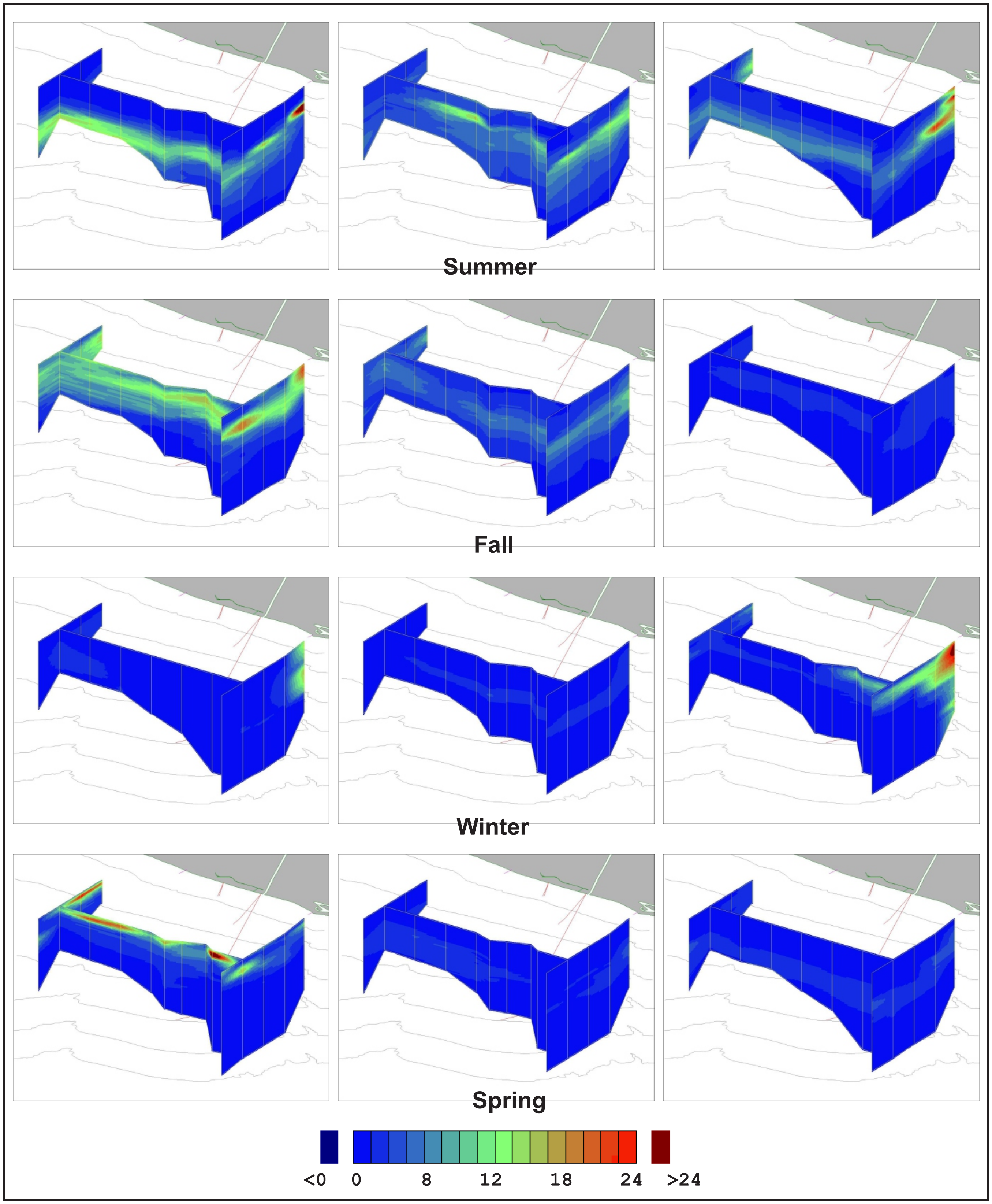


Figure 3-25. **Seasonal patterns of chlorophyll-*a* (µg/L) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

Table 3-6. Chlorophyll bloom determinations by occurrence and percent for OCSD monthly sampling, July 2011 through June 2012.

Orange County Sanitation District, California.

Date	Depth Category	No Bloom	Minor Bloom	Major Bloom	Total Occurrences
July 2011	1-15	578	1	6	585
	16-30	376	40	61	477
	31-45	243	64	11	318
	46-60	233	0	0	233
	61-75	193	0	0	193
	Percent	89.9%	5.8%	4.3%	1,806
August 2011	1-15	722	9	4	735
	16-30	517	50	13	580
	31-45	379	0	0	379
	46-60	290	0	0	290
	61-75	220	0	0	220
	Percent	96.6%	2.7%	0.8%	2,204
September 2011	1-15	396	16	23	435
	16-30	306	24	46	376
	31-45	250	2	0	252
	46-60	185	0	0	185
	61-75	156	0	0	156
	Percent	92.1%	3.0%	4.9%	1,404
October 2011	1-15	92	29	29	150
	16-30	103	1	0	104
	31-45	64	0	0	64
	46-60	52	0	0	52
	61-75	32	0	0	32
	Percent	85.3%	7.5%	7.2%	402
November 2011	1-15	827	164	179	1,170
	16-30	816	78	51	945
	31-45	633	0	0	633
	46-60	463	0	0	463
	61-75	377	0	0	377
	Percent	86.8%	6.7%	6.4%	3,588
December 2011	1-15	435	0	0	435
	16-30	381	0	0	381
	31-45	256	0	0	256
	46-60	184	0	0	184
	61-75	157	0	0	157
	Percent	100.0%	0.0%	0.0%	1,413

Table 3-6 continues.

Table 3-6 continued.

Date	Depth Category	No Bloom	Minor Bloom	Major Bloom	Total Occurrences
January 2012	1-15	424	9	2	435
	16-30	357	2	10	369
	31-45	243	4	3	250
	46-60	179	0	0	179
	61-75	157	0	0	157
	Percent	97.8%	1.1%	1.1%	1,390
February 2012	1-15	870	0	0	870
	16-30	666	0	0	666
	31-45	433	0	0	433
	46-60	328	0	0	328
	61-75	255	0	0	255
	Percent	100.0%	0.0%	0.0%	2,552
March 2012	1-15	375	31	29	435
	16-30	341	6	18	365
	31-45	249	2	0	251
	46-60	179	2	4	185
	61-75	163	0	0	163
	Percent	93.4%	2.9%	3.6%	1,399
April 2012	1-15	313	39	83	435
	16-30	375	0	0	375
	31-45	252	0	0	252
	46-60	188	0	0	188
	61-75	165	0	0	165
	Percent	91.4%	2.8%	5.9%	1,415
May 2012	1-15	873	16	11	900
	16-30	667	16	3	686
	31-45	459	0	0	459
	46-60	350	0	0	350
	61-75	268	0	0	268
	Percent	98.3%	1.2%	0.5%	2,663
June 2012	1-15	435	0	0	435
	16-30	371	0	0	371
	31-45	253	0	0	253
	46-60	180	0	0	180
	61-75	158	0	0	158
	Percent	100.0%	0.0%	0.0%	1,397

decrease back to no blooms in June. Bloom depths stayed above 30 m except in July and January when they reached to the 45 m depth strata.

For each quarter, the chlorophyll-*a* peak was below the 10% light level (Figure 3-23) and was significantly correlated to 1% PAR, 10% PAR, and Secchi (r=0.68, 0.31, and 0.63, respectively). While the 10% light level generally corresponds to minimum levels needed by phytoplankton for photosynthesis, the subsurface layering patterns also correspond to typical sinking depths for phytoplankton (Hardy 1993).

Plume Related Changes in Water Clarity and Coloration
Water clarity and discoloration standards (Criteria C.3.b) were met, as there were no patterns relative to the outfall for chlorophyll-*a*, Secchi depth, water color, and PAR. Plume-related changes in transmissivity and CDOM occurred below the pycnocline or at mid-depth (Figures 3-19 and 3-20). A plume impact would include changes in water clarity that diminishes light as it penetrates water such that it would have an effect on phytoplankton by reducing photosynthesis and inhibiting growth. However, reductions in light levels due to the plume were small (<10% for light transmittance) and below the 10% light level as defined by PAR (Figure 3-23). With the exception of CDOM, water clarity measures at the outfall fell within the ranges of the monitoring area (Figures B-27 to B-30). Compliance with criterion C.3.c was above 97% (Chapter 2) and the overall effect on the "natural" light penetration criterion was, therefore, minimal and not ecologically significant (see Chapter 2).

<u>Nutrients, Bacteria, and Floatables</u>

Ammonia
Ammonia concentrations (NH3-N) were below detection in over 88% of the 2,088 samples collected in 2011-12. Of the 245 samples with detectable ammonia, 197 (80%) occurred below 15 m. Seasonally, there were no differences in mean concentrations, but summer and fall had the highest maximum values, most likely due to stronger water stratification and less plume dilution (Table 3-5). While there were elevated NH3-N concentrations due to the discharge, these values were below the ocean surface. Values above 30 m at outfall Station 2205 all fell within the range of non-outfall stations, while those below 30 m exceeded background values (Figures 3-26 and B-32). While mean and maximum values for 2011-12 were higher than the previous year, spatial patterns and concentration ranges were similar to prior year's results (OCSD 2004–2012). Taking into account the limited vertical and spatial distribution of NH3-N, lack of coincidence with chlorophyll-*a,* and low probability of toxicity, it was determined that compliance with the nutrient criterion (C.4.f) was met.

Bacteria
With continued disinfection of the final effluent, the vast majority (81–92%) of the fecal indicator bacteria (FIB) counts were below the method detection of 10 MPN/100 mL. While all three FIBs were significantly correlated, only total and fecal coliform counts were strongly correlated (r=0.95); the enterococci r-value was 0.24 for both total and fecal coliform bacteria. Total coliform bacteria, which had the highest counts and fewest samples below detection, was used as a "worse-case" example of the impact of bacteria to the receiving water. Elevated total coliform bacteria typically occurred below 15 m (Table 3-5, Figures 3-27 and B-33 to B-35). Spatially, FIBs occurred primarily near the outfall with no

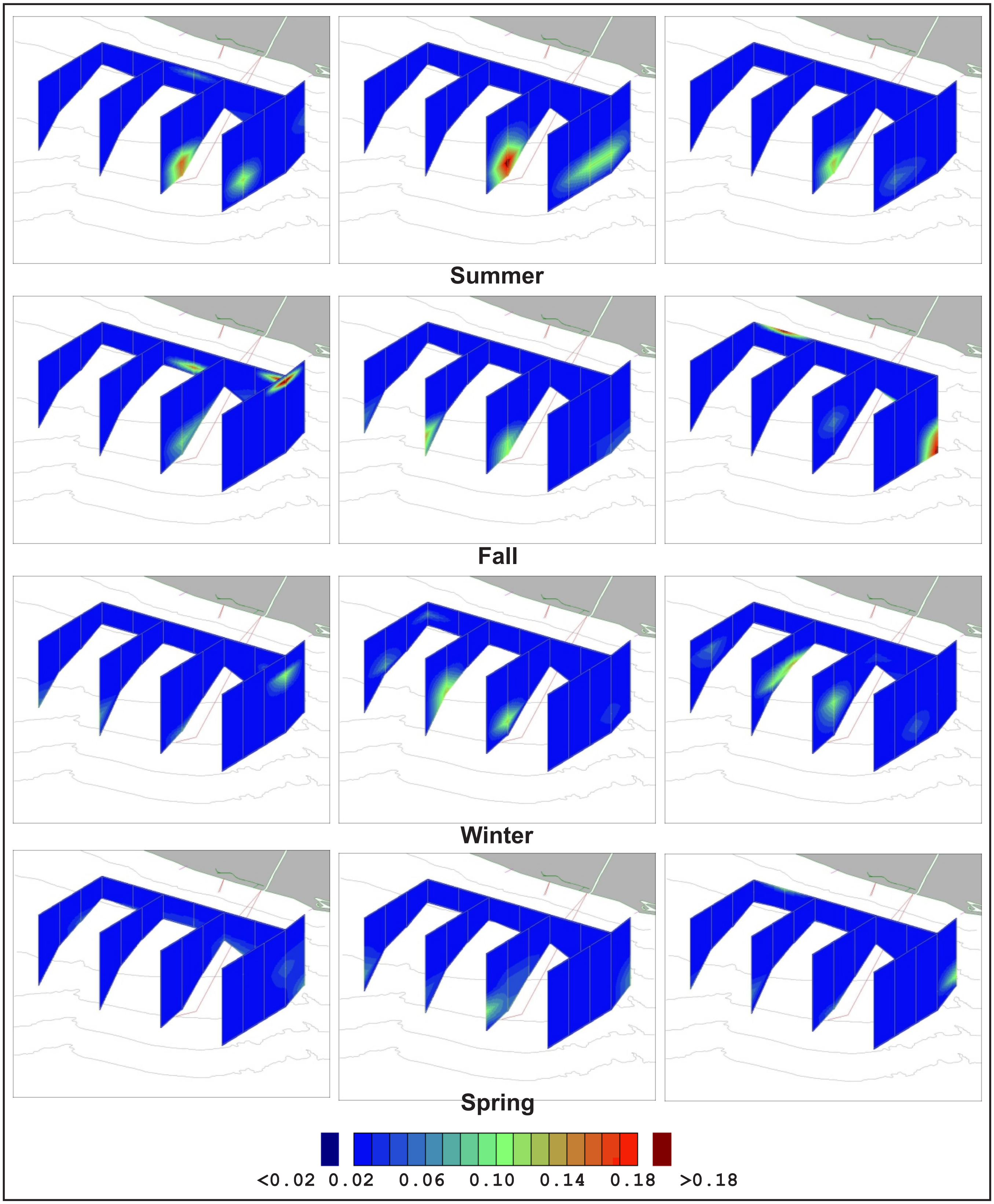


Figure 3-26. **Seasonal patterns of ammonia (mg/L) for summer (July 26, August 22, September 7, 2011), fall (November 2, November 8, December 15, 2011), winter (January 18, February 9, March 7, 2012), and spring (April 18, May 8, June 13, 2012).**

Orange County Sanitation District, California.

Figure 3-27. Seasonal patterns of total coliforms (MPN/100mL) for summer (July 26, 27, August 9, 10, 22), fall (October 27, November 2, 3, 8, 9), winter (February 7, 9, 15, 16, March 7, 2012), and spring (April 18, May 2, 3, 8, 10).

Orange County Sanitation District, California.

evidence of impact at the Rec-1 stations along the 20 m isobath (Figures 3-27, 3-28, and 3-29). Most total coliform samples (73%) were below the detection limit of 10 MPN/100 mL with only one sample (0.8%) greater than the 10,000 MPN/100 mL single sample standard. All offshore criteria for bacteria (C.2.a.1 and C.2.a.2) were met.

Floatables
Observations of grease and floatables address the potential effects from the wastewater discharge to beaches and offshore surface waters. No beach station had any observable grease during 2011-12 (Table B-10). There were also no offshore observations of floatable material related to the discharge or that affected water clarity (Tables B-11 and B-12). These results demonstrated compliance with criterion C.3.a and were consistent with findings from previous years (OCSD 2004–2012).

CONCLUSIONS

Results from the District's 2011-12 water quality monitoring program detected only minor changes in measured water quality parameters related to the discharge of wastewater to the coastal ocean, which is consistent with previously reported results (e.g., OCSD 2011). Plume-related changes in temperature, salinity, DO, pH, and transmissivity were measurable beyond the initial mixing zone during some surveys, but usually extended only into the nearfield stations, typically <2 km away from the outfall. None of these changes were determined to be environmentally significant since they fell within natural ranges to which marine organisms are exposed (Allen et al. 2005; Chavez et al. 2002; Hsieh et al. 2005; Jarvis et al. 2004; OCSD 1996a and 2004; Wilber and Clarke 2001) and compliance with COP criteria remained high (97–99%, Chapter 2).

Prevailing ocean currents and stratification were two of the primary factors in determining the location of the discharged wastewater plume. Current flows for 2011-12 were oriented along the coast (parallel to the depth contours) and had weak, short-lived shoreward flows. Current reversals with depth were more common in the summer when the water column was more heavily stratified. Results were consistent with long-term patterns (Noble et al. 2009, SAIC 2009).
The spatial extent of the wastewater plume was apparent in patterns of salinity and CDOM with changes occurring near the outfall during all surveys, but primarily below 15 m water depth. In contrast, values and patterns in dissolved oxygen and pH primarily responded to natural processes. One exception was apparent reduced oxygen concentration near the outfall due to the secondary entrainment of deeper lower oxygen water caused by the rising effluent plume. These results were consistent with predicted changes in DO and pH levels listed in Table 3-1 using a minimum centerline dilution value of 124:1 from Tetra Tech (2008). Although subsurface (below 45 m) DO dipped to as low as 1.7 mg/L, average DO levels at depth exceeded 3 mg/L, and these lower values were attributed to naturally occurring impingement of deeper ocean waters due either to currents or upwelling.

Light transmissivity was more variable than other measured parameters (e.g., salinity) as it measures particles from multiple sources, such as the disturbance of near-bottom sediments due to waves and currents (resuspension), phytoplankton blooms, rainfall runoff, and the discharge plume. During 2011-12, strong decreases in light transmittance (almost 30%) were associated with the Newport Canyon, while much smaller changes (less than

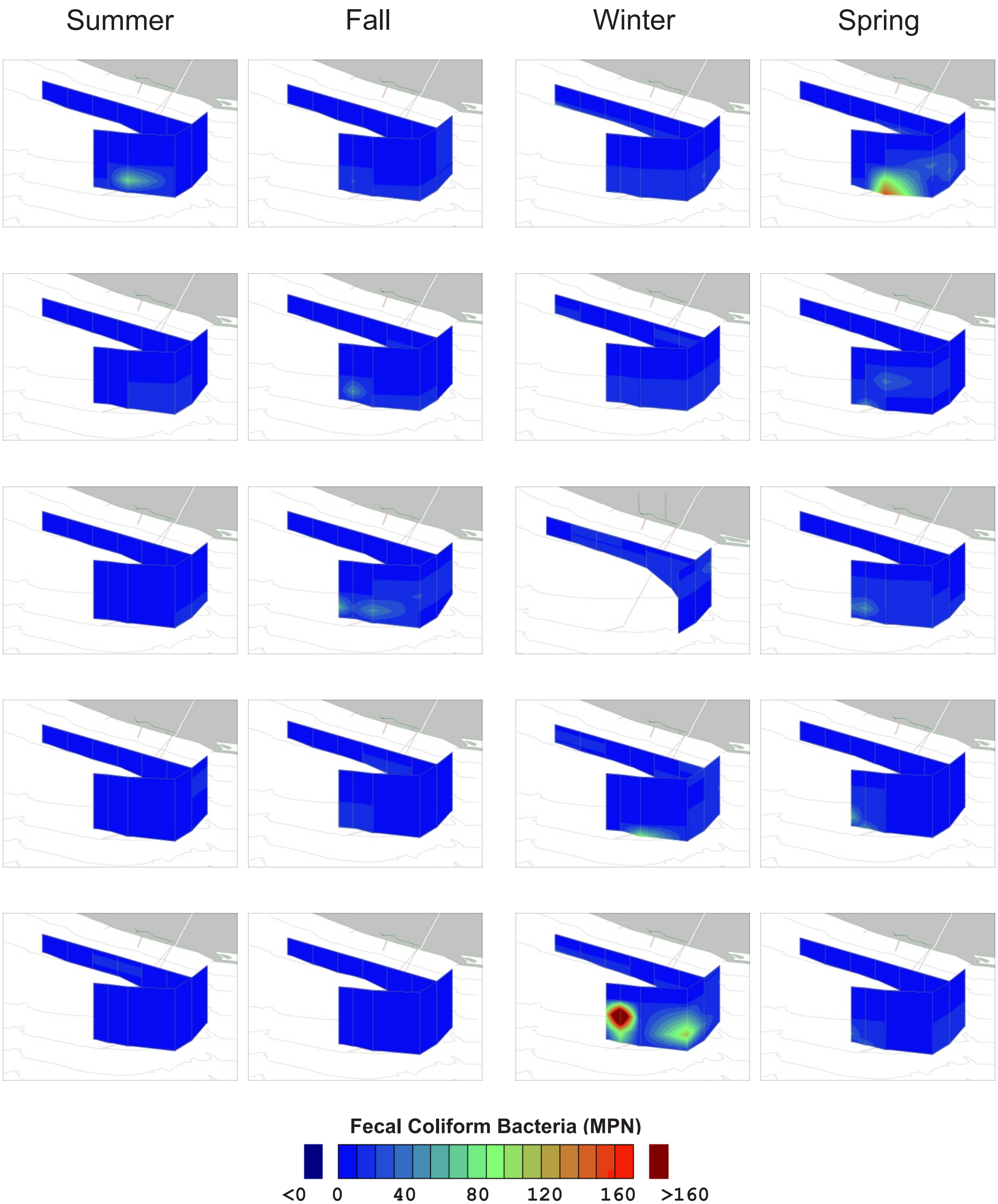


Figure 3-28. **Seasonal patterns of fecal coliforms (MPN/100mL) for summer (July 26, 27, August 9, 10, 22), fall (October 27, November 2, 3, 8, 9), winter (February 7, 9, 15, 16, March 7, 2012), and spring (April 18, May 2, 3, 8, 10).**

Orange County Sanitation District, California.

Figure 3-29. **Seasonal patterns of enterococci (MPN/100mL) for summer (July 26, 27, August 9, 10, 22), fall (October 27, November 2, 3, 8, 9), winter (February 7, 9, 15, 16, March 7, 2012), and spring (April 18, May 2, 3, 8, 10).**

Orange County Sanitation District, California.

10%) were associated with the discharge plume. Light transmittance was most strongly correlated with phytoplankton (chlorophyll-*a* r=-0.55). In all surveys, chlorophyll-*a* and, putatively, the resuspension of bottom sediments within the Newport Canyon had the greatest impacts on water clarity.

Direct measures of the wastewater plume were nutrients (NH3-N) and bacteria. Maximum NH3-N concentrations were 20 times less than COP objective for chronic toxicity to marine organisms (4 mg/L; SWRCB 2005). Average values at all depths and for all seasons were several hundred times lower than this objective. Only 12% of the NH3-N samples were above the detection limit of 0.02 mg/L and the vast majority of these (80%) were below 15 m, typically below the 10% PAR and maximum chlorophyll-a depths. The low levels, along with the lack of association with chlorophyll-*a*, suggests that these concentrations were not environmentally significant.

Prior to disinfection, FIB levels were the primary plume tracer of the discharged wastewater plume. Since disinfection began in August 2002, offshore bacterial concentrations have remained low and predominately below measurement detection levels. This was the case for 2011-12 where 81–92% of the samples fell below the lower MDL of 10 MPN/100 mL.

Overall, the measured environmental and public health effects to the receiving water continue to be relatively small, with values that remain within the ranges of natural variability for the study area and reflected seasonal and yearly changes of large-scale regional influences. The limited observable plume effects occurred primarily at depth, even during the winter when stratification was weakest. In summary, staff concluded that the discharge is not greatly affecting the receiving water environment and that beneficial uses were protected and maintained based on the 2011-12 water quality monitoring results.

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